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Evaluating Bayesian Network Performance in Modeling Occupational Strain and Coronary Heart Disease: A Comparative Analysis of Elimination Order Heuristics

Bhuvan Chandra Sarakam
Student, Doctor of Business Administration, Belhaven University, Jackson, Mississippi, USA

Corresponding Author: * Bhuvan Chandra Sarakam

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Abstract

This paper presents an evaluation of Bayesian Net- work (BN) performance using different elimination order heuris- tics in modeling the relationship between occupational strain (OS) and coronary heart disease (CHD). The study compares three elimination strategies—random order, min-order, and min- fill heuristics—across MAP (Maximum A Posteriori) and MPE (Most Probable Explanation) algorithms. An experiment was conducted with varying Bayesian network sizes to assess run time, number of nodes, and tracked degrees. Results indicate that min- order and min-fill heuristics significantly outperform the random order in terms of efficiency, especially with larger networks. The Bayesian Network model incorporates variables such as gender, job type, mobbing, job demands, income, social opportunities, and various health factors to explore their interplay in OS and CHD. Analysis of prior and posterior marginals, as well as MPE and MAP queries, provides insights into the likelihood of CHD given different conditions. Key findings include the higher likelihood of females reporting CHD, the counterintuitive result that heavy smokers with high job demands are less likely to develop CHD, and the identification of men with active job types as most likely to experience OS. Additionally, d- separation tests show that OS and mobbing are independent of gender and job type in the given context. This study highlights the effectiveness of elimination heuristics in BN reasoning and underscores the complex interrelationships between job strain and health outcomes.

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1. INTRODUCTION

Cardiovascular illnesses remain one of the main sources of mortality on the Western side of the equator. Past the legitimate actual gamble factors related to Coronary illness (CHD), mental viewpoints, for example, character qualities and mental pressure, have collected extensive examination consideration. Among these, work strain, characterized as pressure starting from the workplace, is a noticeable concentration in examinations exploring psycho-social stressors. Notwithstanding broad exploration, its job as a gamble factor for CHD keeps on being discussed. As indicated by the World Wellbeing Association (WHO), word-related strain arises when representatives face work requests and constraints that outperform their capacity to make due successfully.

This study investigates the connection between word-related pressure and the commonness of CHD using a Bayesian Organization (BN) system. The organization consolidates fourteen probabilistic factors alongside their interdependencies. A BN fills in as a factual demonstrating device prepared to graphically address the contingent probabilities and connections among factors inside a particular space in view of exact proof. Such organizations have exhibited their utility in displaying complex communications and conditions actually.

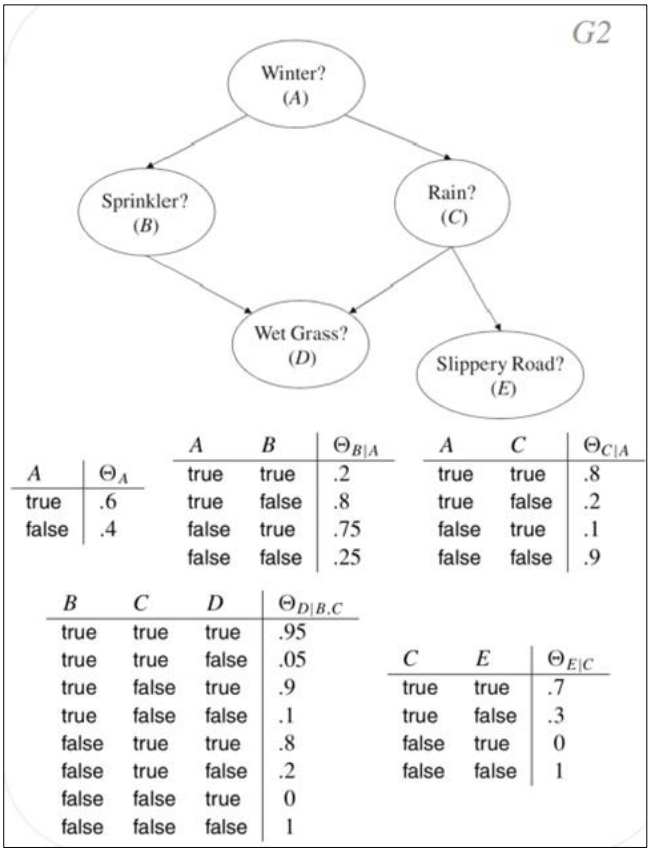
In this paper, the plan and execution of a Bayesian Organization Reasoner are depicted, along with an assessment of its performance. A detailed account of the constructed network, the hypotheses tested, and an analysis of the results and their implications are presented. All tables and figures adhere to the IEEE format and are detailed in the subsequent sections.

2. The Bayesian Organization Reasoner

A Bayesian Organization (BN) is a probabilistic graphical model where hubs relate to irregular factors and coordinated edges address restrictive conditions between these factors. The construction of a BN is characterized as a coordinated non-cyclic chart (DAG) matched with a bunch of contingent likelihood tables (CPTs). For each worth **x** of a variable **X** and every launch **u** of factors **U**, the CPT indicates the likelihood $P(x \mid u)$.

The Bayesian Organisation Reasoner has been created utilising the accompanying calculations:

1. **d-Separation:** The d-partition property in BNs decides if two factors are restrictively free, given a bunch of different factors. Two factors X and Y are d-isolated by Z, assuming each way among X and Y is hindered by Z. In a DAG *G*, X and Y are free given Z if and provided that d-partition holds. To execute this, we: 1. Prune all leaf hubs not in that frame of mind of X, Y, and Z. 2. Eliminate active edges from the factors in Z. 3. Utilize a recursive capability to cross from X, following visited hubs. On the off chance that Y is reachable, X and Y are associated. In any case, they are d-isolated. The result of the d-partition capability is the invalidation of the recursive outcome since network infers reliance.
2. **Variable Elimination:** To process questions, superfluous factors are disposed of utilizing variable end. Given a co-operation chart G and a variable X, the interaction includes: 1. Adding edges between all neighbors of X in G. 2. Eliminating X and refreshing the elements by adding X out.



A	Θ_A
true	.6
false	.4

A	B	$\Theta_{B\|A}$
true	true	.2
true	false	.8
false	true	.75
false	false	.25

A	C	$\Theta_{C\|A}$
true	true	.8
true	false	.2
false	true	.1
false	false	.9

B	C	D	$\Theta_{D\|B,C}$
true	true	true	.95
true	true	false	.05
true	false	true	.9
true	false	false	.1
false	true	true	.8
false	true	false	.2
false	false	true	0
false	false	false	1

C	E	$\Theta_{E\|C}$
true	true	.7
true	false	.3
false	true	0
false	false	1

Fig 1: Examples of Bayesian Networks (BNs)

The request for variable end essentially influences computational proficiency. Two normal heuristics are:

A. **Min-Degree:** Select the hub with the littlest degree (least edges). This is executed by counting the edges of every hub and picking the hub with the littlest count.
B. **Min-Fill:** Select the hub whose disposal presents the least new edges. For every hub, the quantity of extra edges is determined, and the hub with the most reduced count is picked.
3. **Network Pruning:** Network pruning works on the BN by eliminating pointless hubs and edges: - *Node Pruning* Eliminate leaf hubs excluded from the question factors **Q** or proof **e**. - *Edge Pruning* Eliminate edges and change the CPTs in light of the noticed proof *e*.
4. **Marginal Distributions:** The minimal conveyance between two factors **X** and **Y** addresses their joint likelihood dissemination.

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- Prior Marginal The conviction about X before noticing any proof. - *Posterior Marginal* The refreshed conviction about X subsequent to noticing Y.

5. **MAP and MPE Queries:** *MAP* (Greatest Deduced) and *MPE* (Most Plausible Clarification) questions distinguish the most probable launches of factors in the organization.
   - *MAP Queries* Spotlight on a subset of factors, figuring the most likely qualities given proof. - *MPE Queries* Register the most probable task for all factors, barring proof.

For Guide inquiries, both adding out and amplifying out factors are required, while MPE questions exclusively include expanding out factors. These calculations rely upon the proof and the construction of the BN.

3. Performance Evaluation

To assess the proficiency of the executed errands, a trial was led to quantify the typical presentation of the Guide and MPE calculations utilizing three distinct end request proce- dures: arbitrary request, min-request, and min-fill heuristics as depicted in Area II. The measurements utilized for evaluation are as per the following:

Execution time Number of hubs Degree following all through execution

Every heuristic was tried multiple times per calculation, and the normal of these runs is introduced in the resulting plots for the particular measurements.

A. Experiment Setup

The content was created to produce Bayesian organizations for the investigation. Each organization included two root hubs and at least five factors, where every kid hub was related with no less than one parent and, at most, three guardians. The number of hubs in the organization was augmented by ten in every emphasis, bringing about five particular organizations for testing.

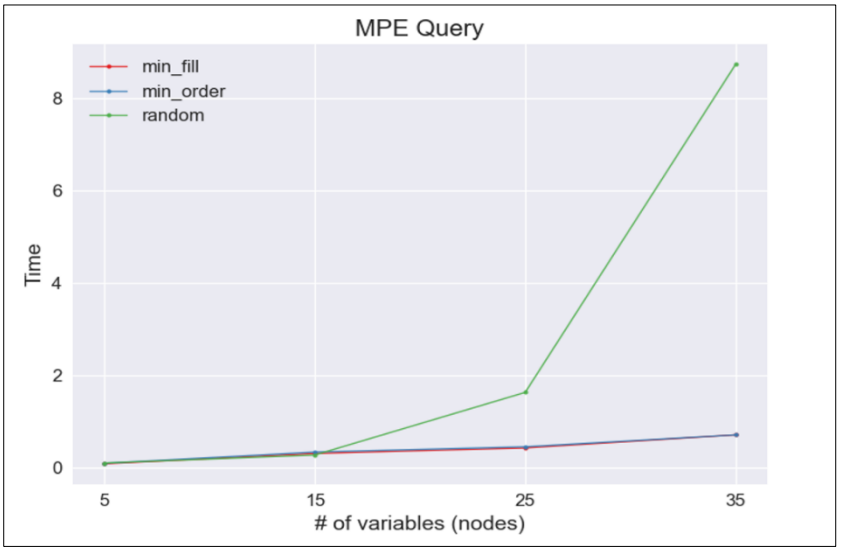
The inquiry boundaries were kept reliable across all or- ganizations to guarantee a fair examination of execution no matter what the particular setup. For both MPE and Guide questions, the proportion of proof given was set to 2.5. For example, a five-hub Bayesian Organization (BN) relates to 5/2.5 proof factors, while a fifteen-hub BN compares to six proof factors. Essentially, the Guide variable proportion was fixed at 2, guaranteeing that proof factors were not chosen as Guide factors.

B. Results

As portrayed in Figure 2, the min-request and min-fill heuristics reliably beat the arbitrary request procedure for both MPE and Guide questions. In the principal chart, the execution times for every one of the three disposal request methodologies are almost indistinguishable for networks with up to fifteen hubs. Be that as it may, as the organization size increments past 25 hubs, the arbitrary request's execution time develops dramatically while the heuristics keep up with stable performance.

In the subsequent diagram, which shows the execution time for Guide questions, a relative expansion in runtime with the number of hubs is seen across all systems. By and by, the arbitrary request system shows the longest execution times, however the thing that matters is less articulated than for MPE questions.

Further assessment of disposal orders was led by follow- ing the levels of each request during inquiry execution. In particular, the quantity of factors in recently made factors was recorded at every disposal step. This worth, addressing the width of the request π, fills in as a proportion of the request's quality. Figures 3 and 4 present histograms showing the recurrence of degrees for networks with five, 25, and 45 hubs.



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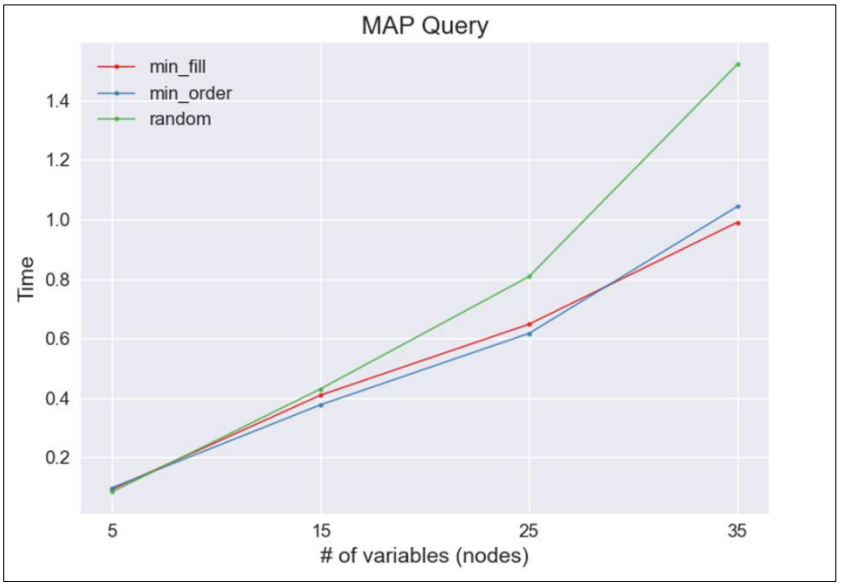
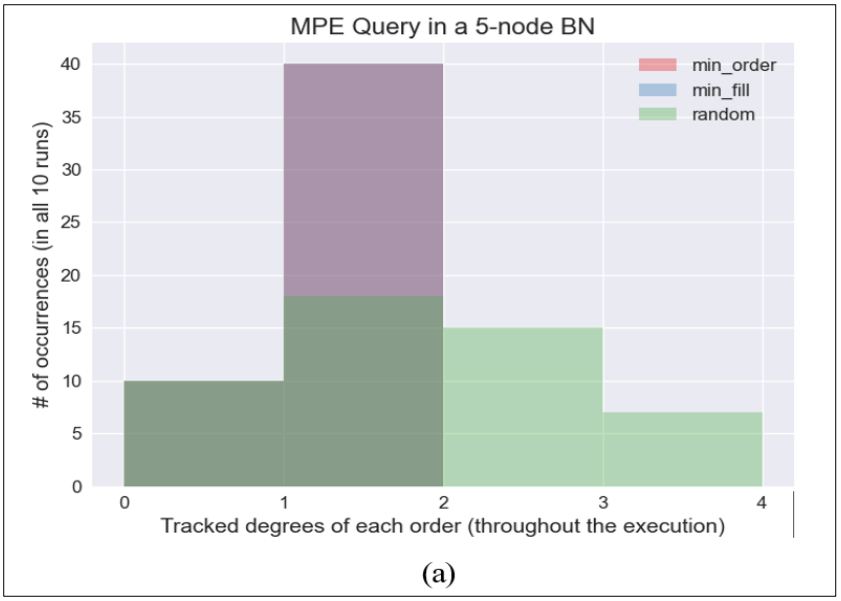


Fig 2: Number of nodes vs. Execution time

The histograms for MPE questions in Figure 3 uncover that the degrees created by the two heuristics cross over reliably across totally tried network sizes. The variance in degrees is negligible contrasted with the irregular request system, which delivers fundamentally higher degrees, connecting with its substandard exhibition as displayed in Figure 2.

For Guide questions, as displayed in Figure 4, the levels of the min-fill and min-request heuristics separate marginally for networks with more than 25 hubs. In any case, the two techniques keep a smaller degree range in contrast with the irregular request, with min-fill exhibiting somewhat better execution generally. The arbitrary request reliably brings about higher degrees, further approving the significance of utilizing heuristics.

In rundown, the exploratory outcomes highlight the ade- quacy of the carried out heuristics contrasted with arbitrary end orders. The computational intricacy is fundamentally de- creased while utilizing all around planned heuristics, prompt- ing further developed proficiency in tackling both Guide and MPE questions.



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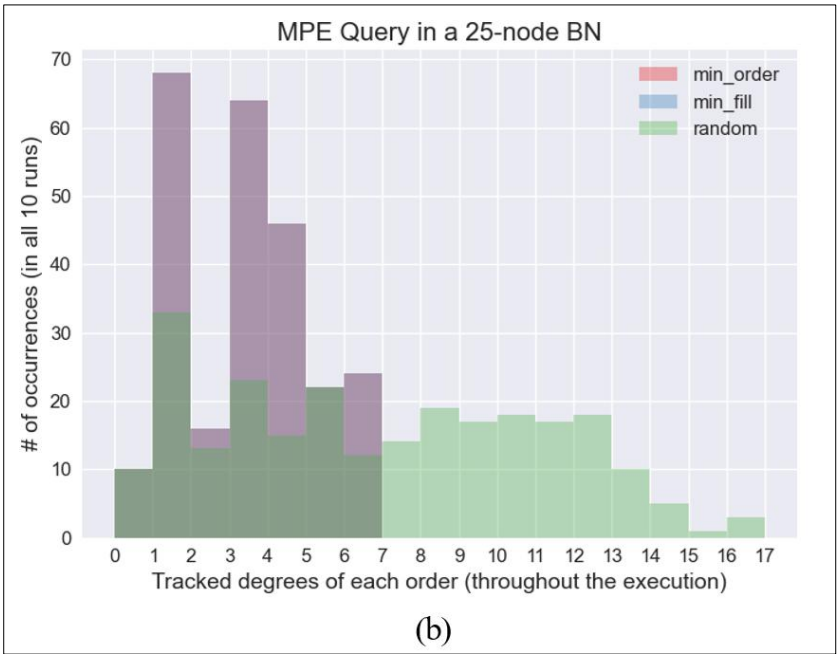

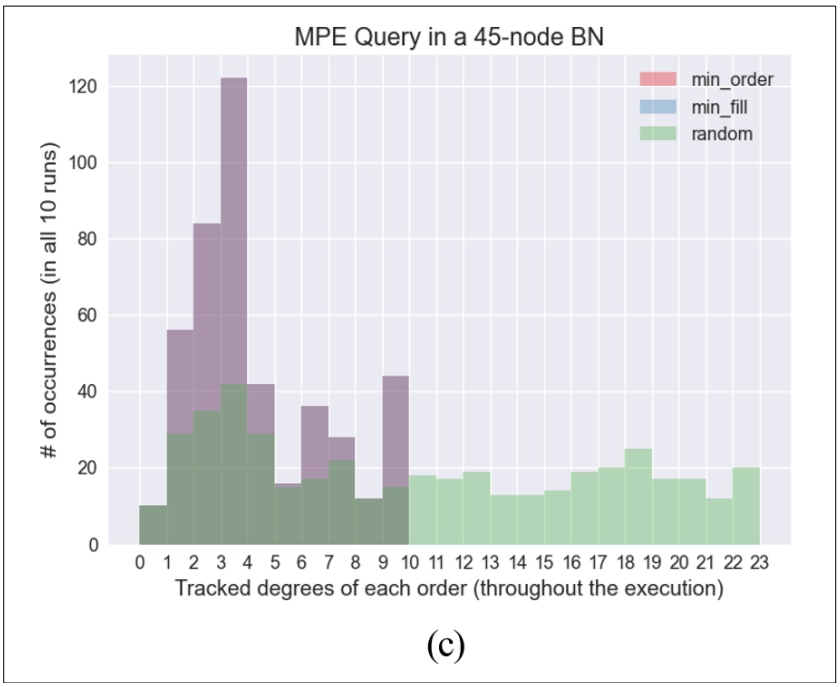

Fig 3: MPE Query Degree Distributions

4. Modeling the Case Study

Case Study - Occupation Stress and Coronary Heart Disease

Our contextual analysis is built in light of an irrefutably factual examination looking at the connection between word- related pressure, named Occupation Strain, and Coronary illness (CHD). Work strain is a huge mental gamble factor, acquiring noticeable quality due to the consistently demanding workplaces in contemporary society. It is a focal concentration for intercession by word-related clinicians to develop the working environment's wellbeing further. Proof connections work strain to various word-related plan factors, large num-

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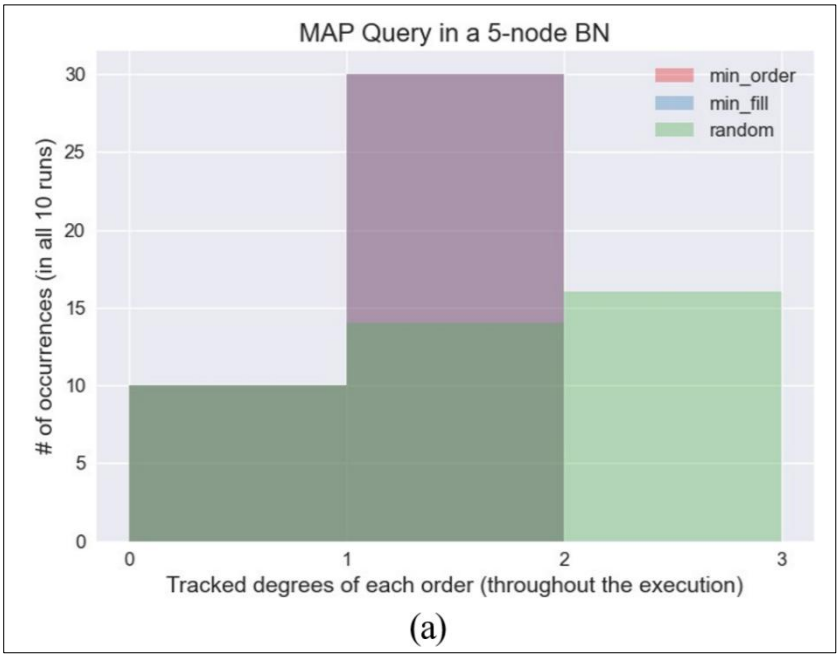
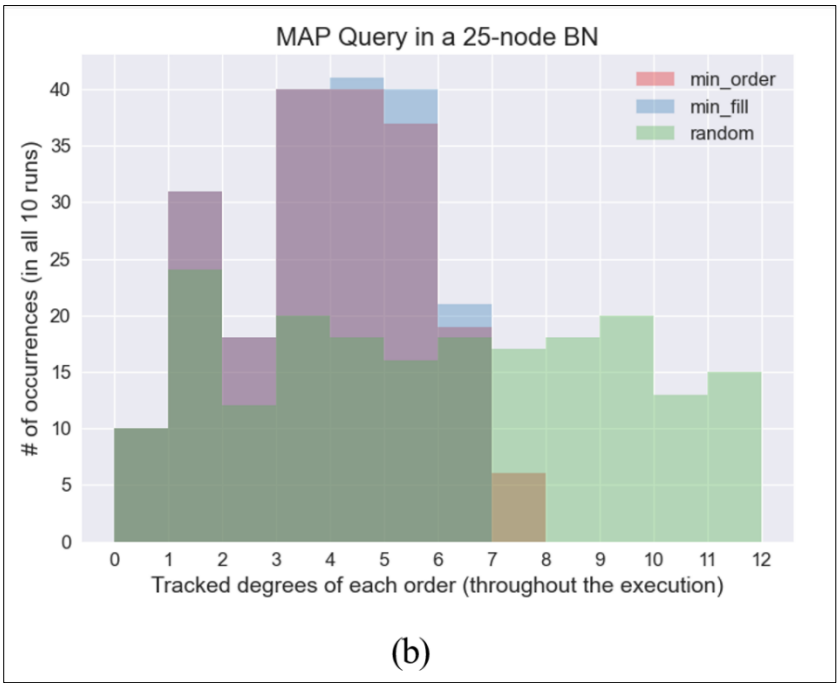
bers of which are associated with a raised gamble of CHD. In particular, research utilizing Karasek's "Request Control Model" demonstrates that high work requests combined with low dynamic power fundamentally increment CHD risk. At the same time, different examinations underscore low work control as an independent indicator of CHD. Moreover, Siegrist's "Exertion Prize Irregularity Model" recommends that unbalanced apparent exertion comparative with remunerations (e.g., pay) assumes a basic part in CHD results. Physiological and mental components intercede this relationship, with elevated cholesterol, hypertension, and maladaptive ways of behaving, like smoking, being basic variables in the model [6].





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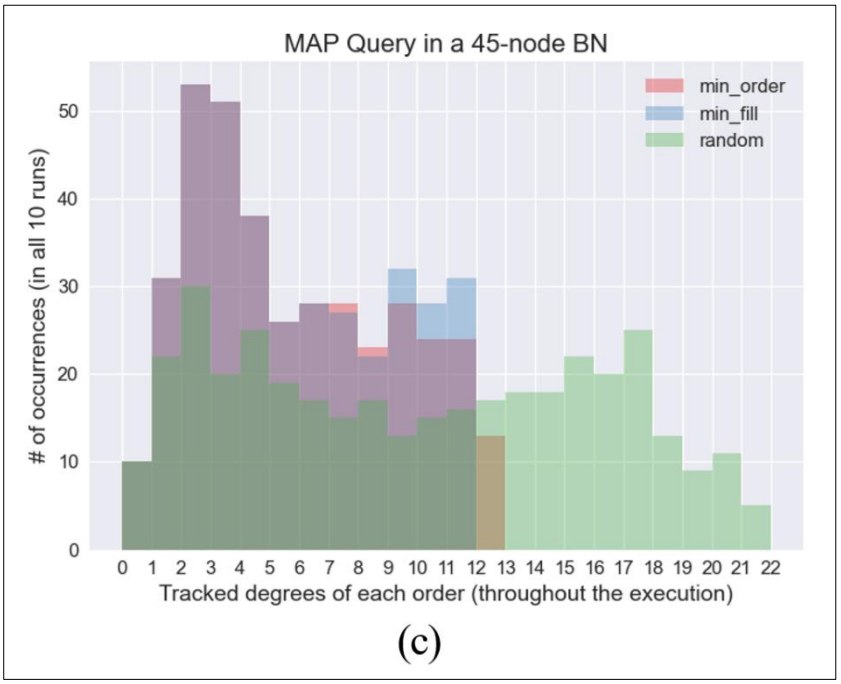

Fig 4: MAP Query Degree Distributions

B. The Bayesian Network

1) Variables:

a) **Sex (S):** Sex is viewed as a root hub with "Male" and "Female" as values. Research shows particular contrasts between genders in regards to work strain and its belongings, with ladies, by and large, revealing more elevated levels of strain than men [7].

b) **Job Class (JC):** Antagonistic work conditions, or- dered into dynamic positions (high requests, high control) and detached positions (low requests, low control), act as another root hub. These classes influence maladaptive ways of behaving unexpectedly, like expanded smoking predominance in detached work settings [3].

c) **Workplace Hostility (WA):** Work environment hostil- ity, otherwise called mobbing, is incorporated as one more root hub, as it is a contributing element to work burnout.

d) **Low Independence (LA) and High Responsibility (HW):** According to the "Request Control Model," the blend of low dynamic power and high work requests prompts raised work strain levels [6].

e) **Perceived Low Compensation (PLP):** Established in the "Exertion Award Awkwardness Model," this variable stresses apparent compensation deficiency compared with work exertion as opposed to outright pay [6].

f) **Limited Social Association (LSI):** Confined social open doors, originating from low compensation, can increment work pressure. These have been connected to social detach- ment, which is viewed as a critical supporter of cardiovascular infection risk [2, 5].

g) **Job Stress (JS):** Occupation stress, characterized as the physical and mental strain coming about because of a lopsidedness between work requests and adapting limit, is a focal variable [1].

h) **Burnout (BO):** Burnout is described by profound depletion, negativity, and mental exhaustion and frequently follows delayed work pressure [1].

i) **Cholesterol (C), Smoking (SM), and Hypertension (HT):** These factors are chosen as middle people connecting position pressure to CHD [6].

j) **Coronary Coronary illness (CHD):** CHD is a particu- lar condition under cardiovascular infections related to physi- ological gamble factors impacted by unfriendly workplaces.

k) **Lung Disease (LC):** Included as an optional variable, cellular breakdown in the lungs is firmly connected with smoking and dietary elements [8].

C. Queries

1) Prior Marginal: We explored the likelihood of being female and determined to have CHD: $P\ (S \wedge CHD)$.

Table I: Prior Marginal

CHD	S	P
F	F	0.3097
F	T	0.1484
T	F	0.3525
T	T	0.1575

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Results show that females are bound to be determined to have CHD than guys, however they are likewise bound to keep away from analysis.

2) Posterior Marginal: Considering that smoking inter- cedes between work strain and CHD, the likelihood of de- veloping CHD under high work demands and smoking was evaluated as $P(CHD = T \mid SM = T, HW = T)$.

Table 2: Posterior Marginal

CHD	P
F	0.6658
T	0.3342

Results show a 66.58% probability of not creating CHD contrasted with 33.41% under these circumstances.

3) MPE: We surveyed the most plausible occasions under the state of elevated cholesterol or hypertension:

Table 3: MPE - Part 1

S	JC	HW	PLP	LSI	WA	BO	HT
F T T	F F T	T T T	F T T	T F T	F T T	F T T	T F T

Table 4: MPE - Part 2

LA	JS	LC	C	SM	CHD	*p*
F	T	T	T	F	F	0.0020
T	F	F	T	T	T	0.0020
T	F	T	T	T	T	0.0026

Results feature the most elevated likelihood (0.2603%) when an individual has both elevated cholesterol and hyper- tension.

4) MAP: We analyzed the most probable qualities for sex and occupation type given proof of JS = T and LSI = F:

Table 5: Map

S	JC	P
T	T	0.050574

MAP results recommend that guys in dynamic work classes are probably going to encounter this situation (P = 0.051).

5) d-Separation: We tried whether CHD and LC are autonomous of sex and occupation type, given operating system = T and WA = T. d-Partition was affirmed to be valid.

5. CONCLUSIONS AND DISCUSSION

This study included the improvement of a Bayesian Organization Reasoner by incorporating calculations, for example, d-partition, variable requesting, network pruning, peripheral circulation calculation, Greatest Deduced (Guide), and Most Plausible Clarification (MPE). A trial assessment was directed to dissect the typical presentation of the Guide and MPE calculations compelled: arbitrary request, min- request, and min-fill heuristics. The outcomes showed that both min-request and min-fill heuristics essentially beat the arbitrary heuristic regarding computational productivity and accuracy.

The reasoner, improved by these heuristics, was applied to a utilization case investigating the connection between word-related Strain (operating system) and Coronary illness (CHD). Five particular questions were tried, giving experiences into different parts of the model:

- The earlier peripheral question proposed that females are genuinely more certain than guys to get both positive and negative conclusions for CHD. This perception might be credited to the way that females will quite often report side effects all the more every now and again to their medical service providers.
- The back minimal inquiry demonstrated that people who are weighty smokers and experience high work requests are measurably almost certain not to foster CHD than to foster it. This outcome was in opposition to the underlying speculation, featuring the connections inside the model.
- The MPE inquiry distinguished that the most probable profile of a person with elevated cholesterol and hypertension incorporates practically all hazard factors being valid. This result lines up with the forecast that the aggregation of chance variables is illustrative of people with increased vulnerability.
- The Guide question uncovered that within the sight of word-related strain and limited social open doors, the most probable profile compares to a male with a functioning position type
- Finally, the d-partition examination tried to determine the autonomy of CHD and cellular breakdown in the lungs from orientation and occupation type, considering that both word-related strain and mobbing were valid. The outcomes affirmed that these factors are for sure autonomous under the given circumstances, as shown by the d-partition outcome.

This examination highlights the utility of Bayesian Organizations in breaking down complex interrelations inside datasets, offering critical bits of knowledge into the probabilistic conditions and independencies of different elements. Future work could investigate the expansion of this system to integrate extra gamble factors or option probabilistic thinking calculations for improved execution.

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