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Extending Dynamic Bayesian Networks in pyAgrum for Multi-Temporal Modeling

Implementation, Inference, and Structure Learning for Temporal Modeling

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A **Bayesian Network** (BN) is a probabilistic graphical model that represents a set of variables and their conditional dependencies through a directed acyclic graph (DAG). Each node in the network corresponds to a random variable, and edges represent probabilistic dependencies between them. BNs are widely used for reasoning under uncertainty, as they allow for the computation of marginal distributions and conditional probabilities, making them ideal for tasks involving decision-making, diagnosis, and prediction.

When extended to dynamic systems, **Dynamic Bayesian Networks** (dBNs) model the evolution of variables over time. In a dBN, the network's structure and parameters are time-dependent, capturing how the relationships between variables change over successive time steps. dBNs are valuable for modeling sequential processes such as [speech recognition](https://en.wikipedia.org/wiki/Speech_recognition), [digital forensics](https://en.wikipedia.org/wiki/Digital_forensics), and [bioinformatics](https://en.wikipedia.org/wiki/Bioinformatics), where time plays a critical role in understanding and predicting outcomes.

However, the current implementation of dBNs in the **pyAgrum** library has limitations. The library primarily supports one-step temporal transitions, which restricts its applicability to more complex dynamic systems where multiple time steps need to be modeled simultaneously. This limitation hinders its ability to capture more intricate temporal dependencies that are often present in real-world applications.

To address this challenge, our project aims to extend pyAgrum to support multi-step time windows (e.g., 2, 3, or 4 steps) for dBN modeling. This extension will enable more accurate representation and inference of dynamic systems, providing a more flexible and powerful tool for modeling and reasoning in temporal domains. Additionally, we will focus on enhancing the visualization and inference as well as structure learning capabilities to ensure that the extended functionality is both accessible and effective for practical use cases.