HUGIN Expert White Paper

White Paper

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Company Profile

HUGIN Expert A/S is a leading provider of software for artificial intelligence and advanced decision support based on complex statistical models called Bayesian Networks (BN). Established in 1989, HUGIN Expert has designed development tools and software for building decision support systems based on BN-technology for almost 25 years. Our software products are used in virtually every area of business in a wide range of applications, including decision support, fraud detection, credit default prediction, medical diagnostics, troubleshooting, risk analysis and safety assessment.

HUGIN software utilizes the most efficient and exact algorithm for updating probabilities. The algorithm was developed by the group behind HUGIN Expert, and was published in its basic form by Steffen L. Lauritzen of Aalborg and David Spiegelhalter of Cambridge in the Journal of the Royal Statistical Association from 1988, which won the “Outstanding Application Award” of the American Statistical Society in 1989.

Today, the main business of HUGIN Expert is to provide its customers with advanced decision support tools that can add intelligence and efficiency to their products and services. Since its foundation, HUGIN Expert has collaborated with some of the world’s largest software companies and research institutions, and our Bayesian network technology has been utilized in numerous areas of software development. At HUGIN Expert our goal is to provide individual solutions based on advanced BN technology that can help our stakeholders differentiate their products and services and gain a competitive edge for their businesses.

Our vision at HUGIN Expert is to expand our role as a leading provider of artificial intelligence solutions based on Bayesian Network technology.

Our vision at HUGIN Expert is to continue to develop the most advanced BN-technology on the market, and to solidify our position as a leading supplier of Bayesian network technology. Also important for HUGIN Expert is to stay at the forefront with regard to the latest research in Bayesian Network software analytics, and continue to develop software that lives up to the needs and expectations of our customers. Innovation and product development is a core focus area at HUGIN Expert, and we will continually strive to improve established solutions and identify new areas of application for our decision support products. All product and solution developments that are suitable for patenting or trademarks will be protected.

At HUGIN Expert we employ engineers and software developers with knowledge and experience in Bayesian Network influence diagrams, and strive to provide challenging tasks within a dynamic development environment. The key players in our company all have an ownership stake in HUGIN Expert, and as such have a key interest in the continual and successful development of the company. Located in Aalborg, Denmark, HUGIN Expert is in the heart of the world’s largest Bayesian Network technology cluster, and maintains close ties with the heart of the Bayesian community, Aalborg University.

Our international orientation at HUGIN Expert is very strong, and international sales account for over 90% of our business.

Our Logo

HUGINEXPERT

Our company logo has a dual meaning.

HUGIN is an acronym that stands for **Handling Uncertainty in General Inference Networks**. Hugin is also the name of a raven from Nordic mythology.

One of the God Odin's two ravens, Hugin's job was to soar the skies and gather news and intelligence. At the end of the day he would whisper the information from far and wide into Odin's ear.

The raven HUGIN is placed within a crystal ball, symbolizing not only wisdom and intelligence, but also the ability to see into the future to and predict future outcomes.

Bayesian Networks

Defining artificial intelligence can be problematic due to the connotations associated with the word “intelligence”.

It may be more useful to list some of the characteristics of devices or services which can be described as possessing artificial intelligence. For instance, a device or service made by man could be described as acting intelligently if the device or service can

- efficiently solve problems of reasoning and decision making under uncertainty
- acquire and extract knowledge from data, experience, and experts
- adjust the behavior to changes in the surrounding environment and efficiently respond to new situations

It can be said that the goal is to develop computer systems to solve problems, or assist people in solving reasoning problems or decision making under uncertainty using an explicit representation of knowledge and reasoning methods employing that knowledge.

What is a Bayesian network?

A Bayesian network (a.k.a. Bayes net, causal probabilistic network, Bayesian Belief Network, or simply belief network) is a compact model representation for reasoning under uncertainty.

A problem domain – diagnosis of mechanical failures, for instance – consists of a number of entities or events. In a Bayesian network these entities or events are represented as random variables. For example, one random variable can represent the event that a piece of mechanical hardware in a production facility has failed.

The random variables representing different events are connected by directed edges that describe relations between events. An edge between two random variables X and Y represents a possible dependence relation between the events or entities represented by X and Y. For Instance, an edge could describe a dependence relation between a disease and a symptom – diseases cause symptoms. Thus, edges can be used to represent cause-effect relations.

The dependence relations between entities of the problem domain are organized as a graphical structure. This graphical structure describes the possible dependence relations between entities of the problem domain, e.g. a Bayesian network model for diagnosing lung cancer, tuberculosis, and bronchitis would describe the cause-effect relations between the possible causes of these diseases.

The uncertainty of the problem domain is represented through conditional probabilities. Conditional probability distributions specify our belief about the strengths of the cause-effect relations, e.g. lung cancer does not always produce a positive (bad) chest X-ray, and a mechanical failure does not always cause an alarm to sound. Thus, a Bayesian network consists of a qualitative part, which describes the dependence relations of the problem domain, and a quantitative part, which describes our belief about the strengths of the relations.

The example below describes a simple hypothetical medical diagnosis situation where a patient consults a chest clinic. The fictitious qualitative medical knowledge is:

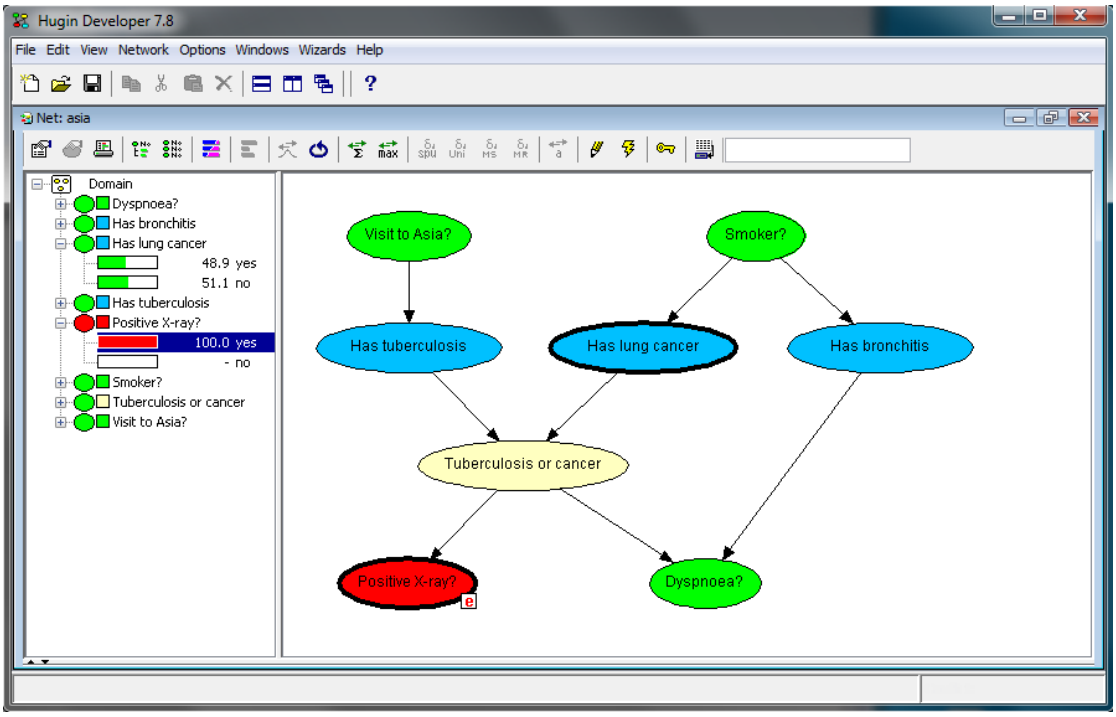

Figure 1. A simple model of a hypothetical medical diagnosis situation

Shortness-of-breath (dyspnoea) may be due to tuberculosis, lung cancer or bronchitis, or none of these or more than one of these. A recent visit to Asia increases the chances of tuberculosis, whereas smoking is known to be a risk factor for both lung cancer and bronchitis. The results of a single chest X-ray do not discriminate between lung cancer and tuberculosis, as neither does the presence or absence of dyspnoea.

The qualitative medical knowledge can be represented as a Bayesian network as shown in Figure 1. This Bayesian network model can support the medical doctor of the chest clinic in her or his reasoning about whether or not a patient suffers from bronchitis, lung cancer or tuberculosis.

Usually, we do not have complete knowledge about the state of the world, i.e. there are some things we do not know for certain. An observation is a piece of knowledge about the exact state of the world. When we make observations, or in some other way obtain additional knowledge about the state of the world, we use this knowledge to update our belief about the state of the world. If for instance a medical doctor makes the observation that a patient is suffering from dyspnoea, then the medical doctor has a stronger belief that the patient is suffering from lung cancer or bronchitis than he would have had, had the patient not suffered from dyspnoea. This is a typical example of reasoning under uncertainty.

A Bayesian network can be used to compute the probability of different events or hypotheses given a number of observations, e.g., how likely is it that the patient is suffering from lung cancer given our knowledge that she has recently been on a visit to Asia, and the result of a single X-ray was positive? A query of this kind can be solved efficiently using a Bayesian network.

The theory behind Bayesian networks

The foundation of Bayesian networks is the following theorem known as Bayes' Theorem:

$$P(H \mid E,c) = \frac{P(H \mid c)\, P(E \mid H,c)}{P(E \mid c)}$$

It is named after Reverend Thomas Bayes (1702-1761), an 18th century Nonconformist minister from England who derived a special case of this theorem, see Figure 2.

Figure 2. Reverend Thomas Bayes.

The derivations made by Bayes were published in 1763, two years after his death. Exactly what Bayes intended to do with the calculations, if anything, remains a mystery today. However, the theorem as generalized by Laplace is the basic starting point for inference problems using probability theory as logic. The theorem describes how to update our beliefs about the state of the world in the light of observations.

Why use Bayesian networks?

The framework of Bayesian networks offers a compact, intuitive and efficient graphical representation of the dependence relations between entities in a problem domain. The graphical structure reflects properties of the problem domain in a visually intuitive way, which makes it easy for non-experts in Bayesian networks to understand and build this kind of knowledge representation. It is possible to utilize both background knowledge such as expert knowledge, and knowledge stored in databases when constructing Bayesian networks.

The compactness and efficiency of Bayesian network models have been exploited to develop efficient algorithms for solving queries. For example, queries like, "What is the probability that a person applying for a loan will repay this loan given that we know customer age, gender, income, and financial status?" can be answered efficiently.

We may or may not be satisfied with the computed the answer to a query. In some cases we may want to analyze the results of a query. For instance, in medical diagnosis situations where a patient has been assigned a dangerous or high-risk treatment, the patient would like an explanation as to why the treatment is needed. Bayesian networks support this form of reasoning. Similarly, some of the observations we make about the state of the world may conflict with each other. The results of two different tests may conflict in such a way that one result indicates the patient is not suffering from a disease, the other result that he does. Data conflict analyses can be used to identify, trace, and resolve possible conflicts in the observations made.

During the interview of a person applying for a loan, the banker may be concerned with whether or not the person will actually repay the loan. During the interview the banker collects

information about the applicant. If based on this information the banker believes with a high degree of certainty that the person will repay the loan, the banker may wonder how sensitive her conclusion is to the answers supplied by the applicant – *what if the applicant had answered certain questions differently?* This kind of sensitivity analysis can be performed using Bayesian networks.

In a decision-making scenario it may be beneficial for the decision maker to acquire additional information before a decision is made. An example is a decision on whether or not to drill for oil at a specific site. The result of an additional test may change the decision, but is it worth the cost to perform the test? This kind of value of information analysis is also supported by Bayesian networks. In fact, a large number of different techniques exist that can be applied to analyze the results obtained from queries against a Bayesian network model.

How are Bayesian networks used?

Bayesian networks can and have been used as components for reasoning under uncertainty in large and complex systems.

Consider, for instance, a large medical diagnosis system available to medical doctors on the Internet. Such a system could consist of a large number of components where each component can be used to diagnose a set of different, but related, diseases. Through a computer each medical doctor could interact with the system when diagnosing patients in order to make better diagnoses or to confirm a diagnosis. One component of such a large and complicated system, for instance, could be a component for diagnosing lung cancer, bronchitis and tuberculosis as with the Chest-Clinic example. Another component could support diagnosis of different diseases.

Figure 3. Bayesian networks are most often used as components for reasoning under uncertainty in complex systems or applications.

The above example illustrates the typical usage of Bayesian networks in normative systems.

What have Bayesian Networks been used for?

HUGIN Bayesian network software has been utilized to develop solutions for reasoning and decision making under uncertainty in a wide variety of application areas. For example:

Health Care – TREAT Decision support system to address problems connected with multi-resistant bacteria and identify appropriate antibiotic treatment.

Telecommunications - Troubleshooting software to identify potential faults in complex mobile networks, reducing fault incidents and improving resolution times.

Information Processing – Information filtering and information display for time-critical decisions and fault analysis in aircraft control.

Industry – Risk assessment solution for offshore production facility removal, the diagnosis of on-board repair solutions for unmanned underwater vehicles, and process control systems for wastewater purification.

Finance – FDM automated fraud detection solution for claims handling, the BayesCredit mortgage default prediction solution, and the M-star risk compliance solution.

Military – NATO Airborne Early Warning & Control Program and situation assessment.

Agriculture – RIBAY web-based system for risk and finance prediction in pork farming and agriculture, and the BIOTRACER tool for tracing feed and food contamination.

HUGIN Products and Services

Adding BN-technology to products and services provides a wide range of benefits. Because BN technology can be applied in various process areas and at various business levels, the benefits from HUGIN software depend on business needs and opportunities for improvement.

HUGIN product packages are complete development environments for model-building, testing and experimentation using HUGIN software.

Commercial Licenses:	***Academic Licenses:***
HUGIN Explorer	HUGIN Educational
HUGIN Developer	HUGIN Researcher
HUGIN OEM	HUGIN Classroom

HUGIN Explorer / HUGIN Educational

This package contains a flexible, user-friendly and comprehensive graphical user interface (GUI). The GUI contains a compiler and a runtime system for the construction, maintenance and usage of knowledge bases using Bayesian network technology.

The Hugin Explorer package comes as either a 32-bit or 64-bit application.

Package Content:

- Platform independent graphical user interface - Java based
- A full library of pre-built knowledge bases from various areas
- Extensive help and technology information functionality
  - Package user manual
  - Extensive walk-throughs
  - Examples

HUGIN Developer / HUGIN Researcher

This package contains a flexible, user friendly and comprehensive graphical user interface and the advanced HUGIN Decision Engine (HDE) for application development. The GUI contains a graphical editor, a compiler and a runtime system for the construction, maintenance and usage of knowledge bases using on Bayesian network technology.

The HDE incorporates all the functionality related to handling and utilizing knowledge bases in a programming environment. The HDE is available with application program interfaces (API's) for the major programming languages: C, C++, Java, .NET and an ActiveX-server for e.g. Visual Basic.

The Hugin Developer package comes as either a 32-bit or 64-bit application (the ActiveX-server is only 32-bit).

Package Content:

- Platform independent graphical user interface - Java based
- The HUGIN Decision Engine with application program interfaces for C, C++ and Java. Furthermore, we provide an ActiveX-server for PC-Windows licenses
- A full library of pre-built knowledge bases from various areas

- Extensive help and technology information functionality
  - Package user manual
  - Extensive walk-through's
  - Examples

HUGIN Classroom

This license is a multi-user license equivalent to the HUGIN Educational license, with the following limitations:

Max. 200 states (100 binary nodes) and automated learning from max. 500 cases.

HUGIN OEM

The HUGIN OEM contract is for customers who are interested in distributing products and services that incorporate HUGIN technology, including the right to sublicense our technology as part of their own products or services.

Because we recognize that specific needs of customers are individual and vary, we have a flexible view regarding potential OEM-customers, and OEM fees are determined on an individual basis, depending on the volume, price and nature of the product.

Below are 3 examples of possible HUGIN OEM-models:

Model 1: OEM-holder pays a percentage of the total turnover on a distributed product.

Model 2: OEM-holder purchases the right to a fixed number of distributions per year.

Model 3: A per distribution fee applies in which the OEM-holder pays a fixed fee for each license distributed.

HUGIN Support Pack

HUGIN Support Pack ensures the success of an investment in HUGIN Expert technology. We are committed to providing fast, personalized service to our customers and partners. The HUGIN Support Pack gives you access to following:

- Access to New Releases and Product Updates
- Training Course Discounts
- Discount on Consulting Services
- Personalized Point of Contact
- Multiple Contact Methods
- Notification of Priority Issues
- Priority Involvement in Beta Programs
- On-site Visits

HUGIN Training

HUGIN Expert offers training in the use of Bayesian network and influence diagram functionality contained in the HUGIN tool. Our training courses consist of the following:

- construction and usage of Bayesian networks
- construction and usage of influence diagrams
- methods for analysis of results
- programming using HUGIN APIs

Other topics of special interest can also be covered during the course, depending on the needs and interests of the participants. Both in-house training and external training courses are available.

Besides a theoretical introduction to Bayesian Networks and influence diagrams, training courses incorporate a large number of examples and practical, hands-on modelling exercises.

HUGIN Consulting

HUGIN Expert offers expert consultancy in several areas, including:

- Identification of optimal utilization of technology
- Software development using the HUGIN Decision Engine
- Development of domain-specific knowledge bases
- Verification of technology use

HUGIN Consultants have many years' experience working with Bayesian Networks and their utilization in decision support system applications. Our consultants are expert programmers with experience in C, C++, Java and Visual Basic.

Benefits of HUGIN Expert software

Why HUGIN Software?

HUGIN Expert is the world leader in artificial intelligence based on Bayesian Network technology. Whether you add our BN-technology to your products or services, or you use our software as a single tool, the benefits of using tools and technology from HUGIN Expert are many:

- Product maturity and product optimization provide the world's fastest, most robust Bayesian inference engine
- State-of-the-art capabilities and functionality are based on extensive in-house and external BN research and development
- Practical experience and theoretical excellence combine to form continual product refinements
- High-performance and mission critical systems have been developed for use in virtually all business segments using HUGIN software

Why choose HUGIN Expert?

After deciding to add artificial intelligence to your product or service, selecting HUGIN Expert as technology provider is an ideal next choice. State-of-the-art HUGIN technology combined with extensive developmental experience in Bayesian Network solutions and systems make HUGIN Expert uniquely qualified to help you find the "ideal" competitive edge. Consider this when selecting HUGIN Expert:

- Bayesian network market leader for over 20 years
- Highly skilled research and development team
- Strategic cooperation experience with multinational companies
- Focus on retaining position as leading decision support technology provider
- Part of the world's largest Bayesian research community
- Vast experience with large-scale international R&D projects

Benefits for companies

Companies that add artificial intelligence to their products using HUGIN technology can greatly improve their value and market share. Again and again developmental projects have shown that the pragmatic use of artificial intelligence techniques can deliver real value and differentiation to application solutions. Our experienced consultants can provide advice about how BN-technology can be successfully utilized in your line of business.

Benefits for product users

Artificial intelligence – Bayesian network technology in particular - adds value to products, which is a great benefit for product users. For example, a product could incorporate artificial intelligence to exhibit intelligent behavior by automating decision making and reasoning on behalf of the user, or by learning user behaviors and preferences in order to provide better support for customers when using products, etc.

Benefits for developers

Developers who want to infuse artificial intelligence into their products benefit by using HUGIN development tools for the task. HUGIN technology makes model development and solving modeling issues simple and easy.

HUGIN tools are efficient, reliable and user-friendly, and are available both as a graphical tool and an application programming interface.

The HUGIN application program interface is available in major programming languages so developers can develop systems in their preferred language. The graphical tool is a platform independent tool, which enables developers to use the tool on their favorite platform.

If you need help with application development, or other issues arise during the development process, our experienced technical support staff is always on hand to provide fast assistance and answers.

Contact Information

HUGIN Expert A/S
Gasvaerksvej 5
9000 Aalborg
Denmark.

Phone: +45 96550790
Fax: +45 96550799

General Inquiries: info@hugin.com

Sales Support: sales@hugin.com

Technical Support: support@hugin.com