

"The future belongs to those who see
the possibilities, before they become obvious"

HUGIN EXPERT WHITE PAPER

White Paper



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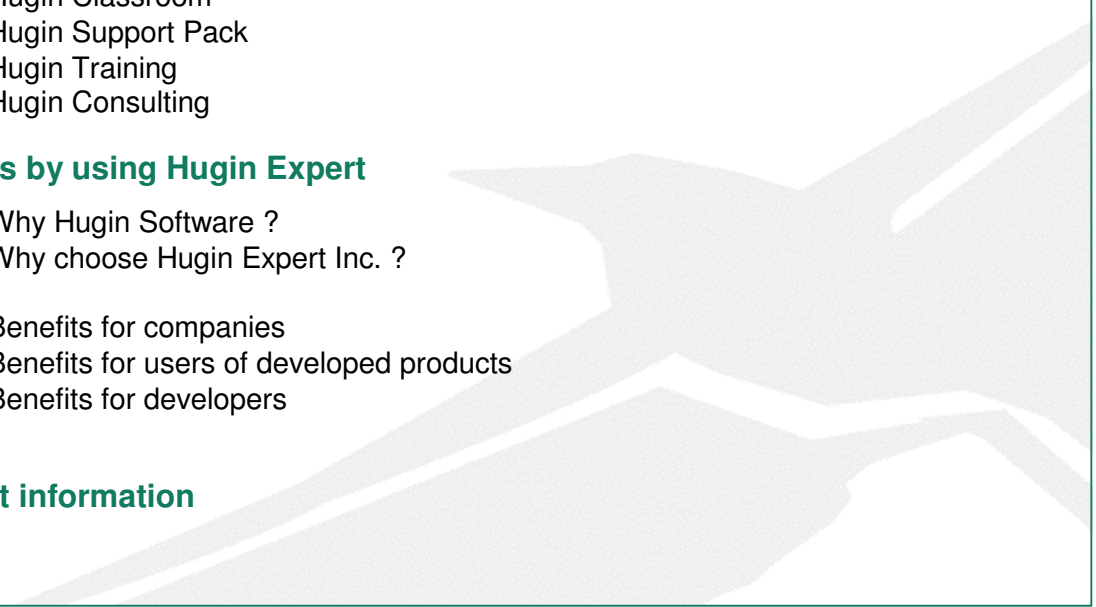
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Company Profile

Hugin Expert A/S has existed since 1989 and is the leading company in developing software for artificial intelligence and advanced decision support based on complex statistical models (Bayesian Networks (BN)). We have, through the last decade, created development tools and other software utilizing BN-technology. Our software products are used in decision support, medical diagnostics, troubleshooting, risk analysis and safety assessment. The Hugin software employs the most efficient exact algorithm for updating probabilities. The algorithm developed by the group behind Hugin Expert was published in its basic form by Steffen L. Lauritzen, Aalborg and David Spiegelhalter, Cambridge in the Journal of the Royal Statistical Association, 1988, and won the "Outstanding Application Award" of the American Statistical Society in 1989.

Today, Hugin Expert's main business is to provide our customers with tools that help them add intelligence into their own products and services. Hugin Expert has over the last decade collaborated with some of the worlds largest software companies and our BN-technology has been utilized in almost any area of software development. Based on this experience, Hugin Expert offers a **Hugin Technology Partnership** to help our customers getting their business just the right competitive edge that differ their products and services from their competitors. Hugin Expert wants to provide our customers with a solution to specific needs based on quality technology and knowledge.

In 2000, Hugin Expert joint partnership with the American company "**Dynasty Technologies Inc.**" which is a leading supplier of enterprise business applications development environments. Dynasty's President & CEO, Bani Brandolini says: *"The solutions we have build based on the Bayesian networks technology from Hugin Expert, show that the pragmatic use of artificial intelligence techniques brings real value and differentiation to application solutions. Also, Dynasty has had excellent support from Hugin Expert on both technical and business development issues, and the relationship is predicted to be a long and profitable partnership."*

It is Hugin Expert's vision to become a highly visible company known as the premium provider of artificial intelligence solutions utilizing Bayesian Network technology.

Hugin Expert's goal is continuing to develop the most advanced BN-technology on the market, and to stay as the leading supplier within BN-technology. It is equally important that Hugin Expert stays in front of the latest research within the area and focuses on developing software that complies with our customers' needs and expectations. Simultaneously Hugin Expert wants to seek new areas, and new products will be introduced continuously. All new developments of products, which are suitable for patenting or trademarks, will be protected.

Such an ambition level requires a solid foundation and it has been created by a solid group of owners, which includes, among other **Hewlett Packard Company**. This gives Hugin Expert the platform necessary to realize the visionary plans for growths.

In 1998, Hewlett-Packard took over 45% of Hugin Expert. In addition to the equity investment, HP and Hugin Expert perform joint research and development. Jim Schreckengast from Hewlett Packard says: *"Hugin Expert's products are, quite simply, the best in the industry. They have the highest performance Bayesian belief inference engine and the most scalable design. They maintain close ties to state-of-the-art research in the field and incorporate the latest innovations in their products. We partner with Hugin Expert, because we know their products can give us an edge in creating smart e-services. Most of these e-services demand that context, experience, risk, and uncertainty are rationally factored into the decision-making process. Bayesian belief network technology, and Hugin's products in particular, excel in this regard."*

Hugin Expert attracts skilful engineers and secure the elite staff through exciting tasks and a dynamic environment for development. The key figures in the company are all joint owners of Hugin Expert, and therefore interested in the development in the company. Hugin Expert is placed in Aalborg, Denmark right next to the worlds largest BN-community, closely linked to Aalborg University.

Hugin Expert has a very strong international orientation, where the export rate stands for about 90 %.

The Raven Logo

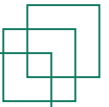


Hugin Expert's Logo shows the raven Hugin, one of Odin's two ravens, Munin and Hugin, who date back to the Norse Mythology.

The ravens fly out and bring back news from every corner of the world. Sitting on the God Odin's shoulder, they whisper the news into his ears.

Munin represents the memory and Hugin the intelligence... and they are his embodied soul.





Bayesian Network

What is Artificial Intelligence?

One of the main problems with the term artificial intelligence is the strong relation to intelligence. In order to define or understand the term artificial intelligence, it is necessary to define or understand the term intelligence. What is intelligence?

The term artificial intelligence does not describe in detail what it is people are doing in the field of artificial intelligence. Instead of using a single term to describe the field of Artificial Intelligence, it may be better to list some of the characteristics of devices or services which we will describe 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

The goal is to develop computer systems to solve problems or assist people in solving problems of reasoning 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. These entities or events are, in a Bayesian network, represented as random variables. One random variable can, for instance, 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 to 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. An edge could, for instance, describe a dependence relation between disease and a symptom – diseases causes 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 the 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 specifies our belief about the strengths of the cause-effect relations, e.g. lung cancer does not always produce a positive (bad) chest X-ray, or 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 following example describes a simple hypothetical medical diagnosis situation where a patient consults a chest clinic. The fictitious qualitative medical knowledge is:



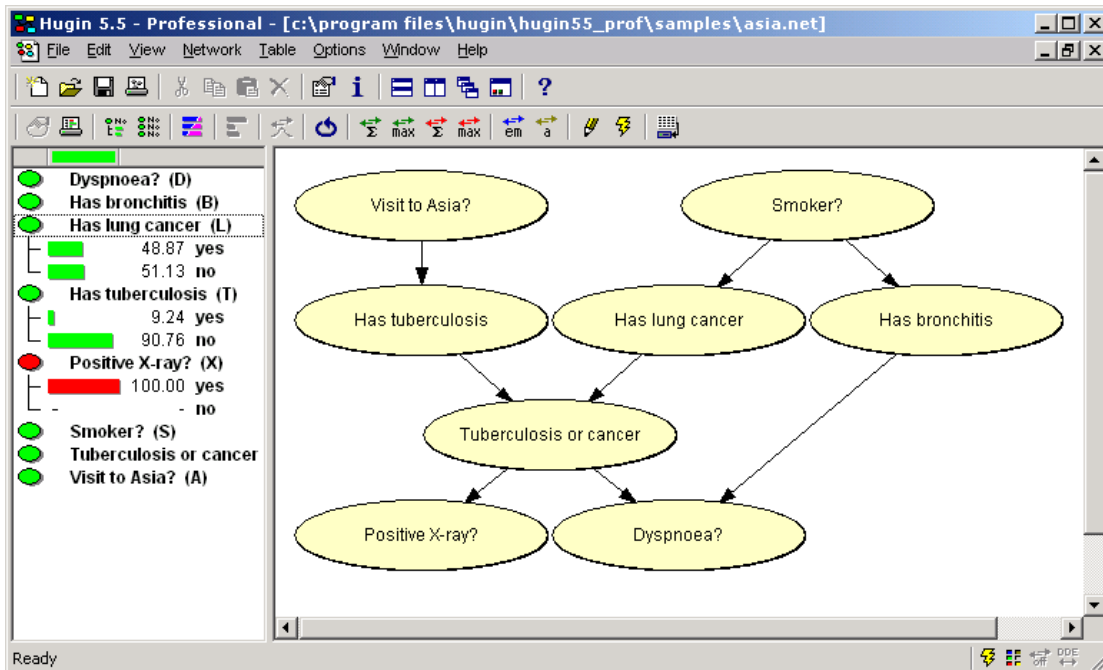


Figure 1 A simple model of a hypothetical medical diagnosis situation

Shortness-of-breath (dyspnoea) may be due to tuberculosis, lung cancer or bronchitis, or none of them, or more than one of them. A recent visit to Asia increases the chances of tuberculosis, while 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 the medical doctor, for instance, makes the observation that a patient is suffering from dyspnoea, then the medical doctor has a higher belief that the patient is suffering from lung cancer or bronchitis than 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 that we know she has recently been on a visit to Asia and that the result of a single X-ray was positive? This kind of query can be solved efficiently using a Bayesian network.

What is the foundation of Bayesian Networks ?

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

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

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, still 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?

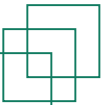
The framework of Bayesian networks offers a compact, intuitive, and efficient graphical representation of dependence relations between entities of a problem domain. The graphical structure reflects properties of the problem domain in an intuitive way, which makes it easy for non-experts of Bayesian networks 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 against. Queries like: "What is the probability that a person applying for a loan will repay this loan given that we know the age, gender, income, and financial status?", can be answered efficiently.

We may not be satisfied with having computed the answer to a query. In some case 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 to have an explanation of why she or he needs this treatment. Bayesian networks support this. Similarly, some of the observations we make about the state of the world may be conflicting. The results of two different tests may be conflicting such that one result indicates that the patient is not suffering from a disease whereas the other result 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 is actually going to repay the loan. During this interview the banker collects information about the applier. If the banker based on this information to a high degree of certainty believes that the person is going to repay the loan, then the banker may wonder how sensitive her conclusion is to the answers supplied by the applier – *what if the applier had answered differently to some question? This 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. In fact, a large number of different techniques can be applied to analyze the results obtained from queries against a Bayesian network model exist.

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 through 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. Each medical doctor could through a computer interact with the system when diagnosing patients in order to make better diagnoses or to confirm a diagnosis. One of the components of such a large and complicated system could, for instance, be a component for diagnosing lung cancer, bronchitis, and tuberculosis like the Chest-Clinic example. Another component could support diagnosis of different diseases.

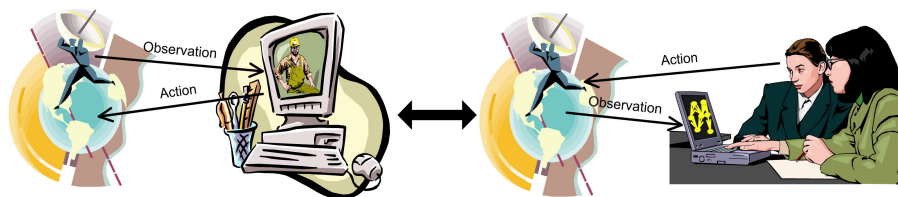


Figure 3: Bayesian networks are most often used as components for reasoning under uncertainty in complex systems or applications.

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

What have Bayesian Networks been used for?

Bayesian networks have been applied for reasoning and decision making under uncertainty in a large number of different settings. A few of the applications are indicated in the list below:

Medicine – diagnosis of muscle and nerve diseases, antibiotic treatment, diabetes advisory system, triage (AskRed.com).

Software – software debugging, printer troubleshooting, safety and risk evaluation of complex systems, help facilities in Microsoft Office products.

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

Industry – diagnosis and repair of on-board unmanned underwater vehicles, control of centrifugal pumps, process control in wastewater purification.

Economy – credit application evaluation, portfolio risk and return analysis.

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

Agriculture – blood typing and parentage verification of cattle, replacement of milk cattle, mildew management in winter wheat.





Hugin Technology Partner Program

What can Hugin Expert do to help?

We know, at Hugin Expert, that in today's complex world no single company can hold all the answers. That is why Hugin Expert offers a strong partnership to help your business getting just the right competitive edge that differ your products or services from your competitors.

The advantage for you is that you do not have to develop and maintain advanced technology yourself. Hugin Expert has over the last decade collaborated with some of the worlds largest software companies and our BN-technology has been utilized in almost any area of software development.

Due to our years of experience within the area, we can help you "catch" the competitive edge that fits your products or line of services.

Being a Hugin Technology Partner you will have a personal contact at Hugin Expert, who is in charge of your partnership. This ensures that your business and your specific needs are well known by the staff at Hugin Expert, and that you are sure to always talk to a highly qualified supporter with knowledge of your business needs.

What benefits do I gain by being a Hugin Technology Partner?

Being a Hugin Technology Partner gives you access to a partner package containing all you need to successfully incorporate Bayesian technology into your line of business. The package contains the following items (Items marked with a * are mandatory)

- Our Bayesian technology development software package*
- The right to incorporate Bayesian network functionality to your own line of products and services*
- Access to development of partner specified functionality within the BN development environment
 - Due to special development needs
 - Needed to complete/refine your competitive edge etc.
- Development of applications or parts of this, which includes Bayesian technology
- Consultancy
 - For details see *Consultancy* under *Products*
- Course on Bayesian Networks
 - For details see *Course* under *Products*

Which Business advantages do I get by using BN-technology?

Adding BN-technology to your products or services provides you with a wide range of advantages. Exactly what we can do to improve your business depends on your specific needs and opportunities for improvement, as BN-technology can be applied at a large number of different levels and business processes.

How do I engage in a Hugin Technology Partner Program?

Hugin Expert will be happy to give you qualified advice in relation to where BN-technology may be successfully utilized in your line of business. When you have decided that Hugin Expert's partner program would be the right choice for your business, you just have to sign the Hugin Technology Partner contract, and a solid partnership can begin.

If you need to require our complete Hugin Technology Partner Program, please contact us, and we will provide you with further information.





Products

Product packages:

The Hugin product packages are complete development environments for constructing, testing and experimenting for users who work with development environments.

Commercial Licenses:

Hugin Explorer
Hugin Developer
Hugin OEM

Academic Licenses:

Hugin Educational
Hugin Researcher
Hugin Classroom

HUGIN Explorer/Hugin Educational

This package contains a flexible, user friendly and comprehensive graphical user interface. The user interface contains a compiler and a runtime system for construction, maintenance and usage of knowledge bases, based on Bayesian network technology.

Package Content:

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

HUGIN Developer / Hugin Researcher

This package contains a flexible, user friendly and comprehensive graphical user interface and a Hugin Decision Engine for application development. The user interface contains a graphical editor, a compiler and a runtime system for construction, maintenance and usage of knowledge bases based on Bayesian network technology.


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

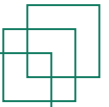
Package Content:

- 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-build 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 limitations. Limited to max. 50 states (25 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 incorporating Hugin technology, including the right to sublicense our technology as part of their products or services.

We are very flexible towards customers who want to engage in an OEM-contract, as specific demands and needs vary a lot. The OEM fee is determined individually depending on the volume, price and nature of the product.

Hugin has 3 different OEM-models to choose from:

Model 1: In this distribution model, OEM-holder pays a percentage of the total turnover on a distributed product.

Model 2: In this model the OEM-holder purchases the right to a fixed number of distributions pr. year.

Model 3: Model 3 uses a pr. distribution fee where the OEM-holder pays a fixed fee every time a license is distributed.

Hugin Services:

Hugin Support Pack

Hugin Support Pack ensures the success of your investment in our technology. We provide unmatched service to our worldwide customers and partners through commitment to customer satisfaction and dedication to personalized support. Purchasing a Hugin Support Pack gives you access to following:

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

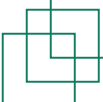
Hugin Training

Hugin Expert offers training in the use of Bayesian networks and influence diagrams in the Hugin tool. The course will consist of four parts:

- construction and usage of Bayesian networks
- construction and usage of influence diagrams
- methods for analysis of result
- programming with the Hugin APIs

Furthermore, topics of special interest to the participants of the course may be covered depending on interest. The Hugin Expert's courses are available both externally and internally.

The course contains a large number of examples, exercises and hands-on experiences. There will be both theoretical and practical exercises.





Hugin Consulting

Hugin Expert offers high expertise consultancy work in regards to:

- Identification of optimal use of technology
- Development of software using our Hugin Decision Engine
- Development of domain specific knowledge bases
- Verification of technology use

Based on many years of experience all our consultancies are very skilful programmers with a wide experience in C, C++, Java and Visual Basic.



Competency, flexibility and creativity are keywords when we take on challenges from our customers.

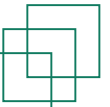
Other Products:

Hugin Clementine Link

Hugin Expert is a part of the Clementine Plus Partner Program, which means that you are able to access and use Hugin Expert's advanced decision support technology through SPSS' enterprise-strength data mining workbench, Clementine.

The integration between Hugin products and Clementine will give the Clementine system an entire new dimension, which will be of great benefit for the customers. The customer will automatically be able to create comprehensive knowledge bases from a set of data. The created knowledge base can be accessed, modified and used from within Clementine, it can be modified and used through our graphical user interface and it can be used in your own software using the power and flexibility provided by the Hugin Decision Engine.





Benefits from using Hugin Expert

Why Hugin Software ?

Hugin Expert is the world leader in artificial intelligence based on Bayesian network, and whether your needs are based on adding BN-technology to your products or services or you just want to use our software as a single tool, you will be provided with a wide range of advantages. In the following we have listed some of the benefits you gain when choosing Hugin Software:

- Product maturity and optimization produce the worlds fastest Bayesian inference engine
- State-of-the-art capabilities based on internal and external research and development
- Practical experience and theoretical excellence combined from the basis of further product refinement
- High-performance and mission critical systems in numerous areas are constructed using Hugin software

Why choose Hugin Expert ?

When you have decided to use artificial intelligence in your products, we are convinced that choosing Hugin Expert as a supplier would be the right choice for you. Hugin Expert offers a strong partnership to help your business getting the right competitive edge that differ your products or services from your competitors. Due to our many years of experience within the area, we are very qualified and will be able to help you “catch” the competitive edge that fits your products or line of service. Some of the main features for you when choosing Hugin Expert are:

- The market leader for more than a decade
- Highly skilled researchers and developers
- International strategic cooperation
- A clear strategy for maintaining its leadership as a tool and technology provider
- Part of the worlds largest Bayesian research group
- Experience from numerous, large-scale international R&D projects

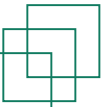
Benefits for Companies

Companies, who want to add artificial intelligence into their products will, by using Hugin technology, gain increased market value. Several projects show that the pragmatic use of artificial intelligence techniques brings real value and differentiation to application solutions. Hugin Expert offers to give your company qualified advice on how the BN-technology may be successfully utilized in your line of business.

Benefits for users of Products

Artificial intelligence – Bayesian network technology in particular - adds value on top of products. This is of great benefit to the user of the products since the additional value is directed at the user. A product could include artificial intelligence to exhibit intelligent behavior, to automate decision making and reasoning on behalf of the user, to learn the behavior and preferences of the user in order to better support the user in the use of the product, etc. These are all properties of the product, which add great value to users of the product.

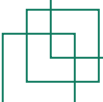




Benefits for Developers

For solving modeling issues, the Hugin technology makes it much easier for you as a developer to build models.

Developers who want or need to add artificial intelligence into their products will benefit from using the Hugin development tools for this task. The Hugin development tools, which are efficient, reliable, and user friendly are available as a graphical tool and as an application programming interface. The Hugin application program interface is available for most major programming languages such that the developer can use her or his own favorite for development. The graphical tool will be available as a platform independent tool such that developers can use the tool on their favorite platform. Finally, help and technical support for the development of application using the Hugin development tools are readily available.



Contacts

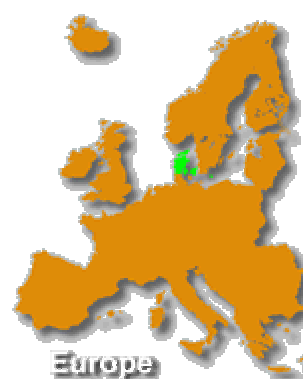


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