

Predicting the BIS during anesthesia

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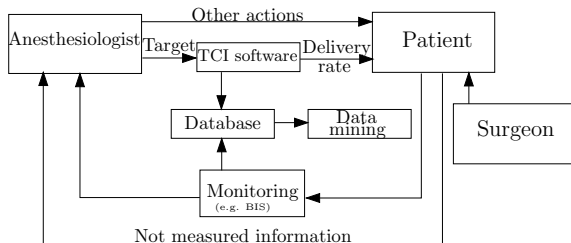
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September 25, 2009

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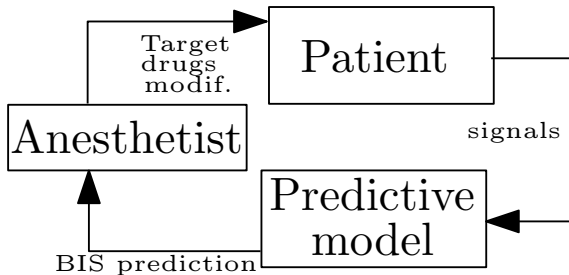
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The data collecting context



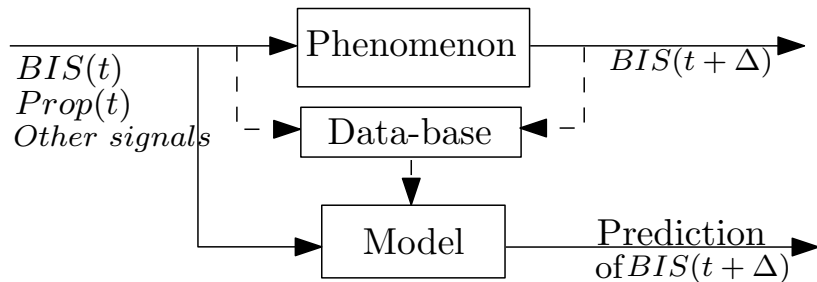
- A TCI anaesthesia software system drives the drugs delivery rate according to the C_e target defined by an anaesthesiologist.
- Anesthetist's actions and some patient's hemodynamic data are stored in a data base.
- Data mining techniques are used to extract relevant information from this database.

The goal



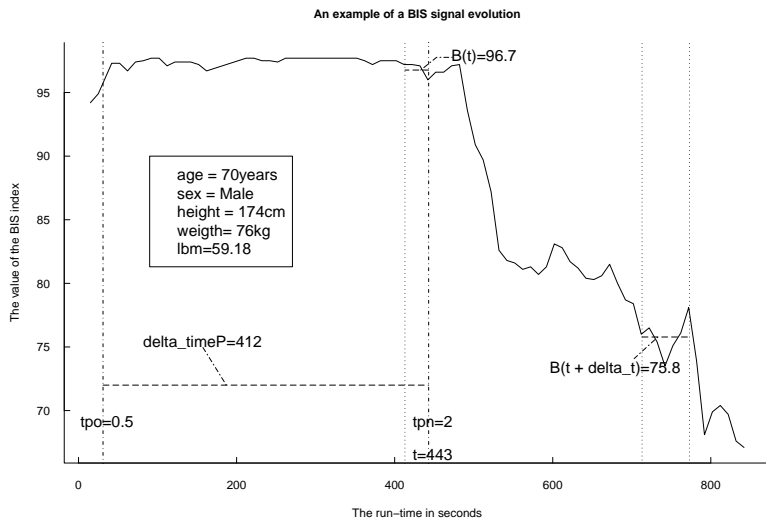
The predictive model can be used by anesthetists during their daily practice.

The goal, refined



A predictive model is built with the database and uses the patient signals to predict the BIS.

The Bispectral Index

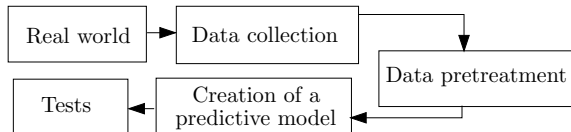


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Data mining definition

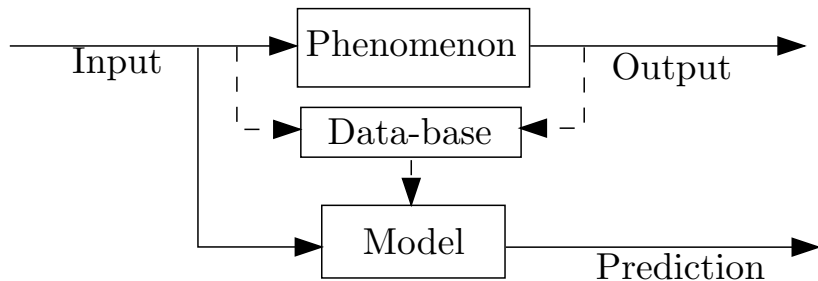
- Data mining is the process of automatically extraction of knowledge from large volumes.
- It is a fairly recent topic in computer science introduced by the need of extracting information form large database.
- But it applies many older computational techniques from statistics, machine learning and pattern recognition.

Data mining steps



- Data are collected in the real world to create a data base.
- A pretreatment is made on the data base, examples :
 - remove the outliers
 - normalization
 - variable selection
- The best parameters of a model are estimated.
- The resulting model is tested to estimate his accuracy.

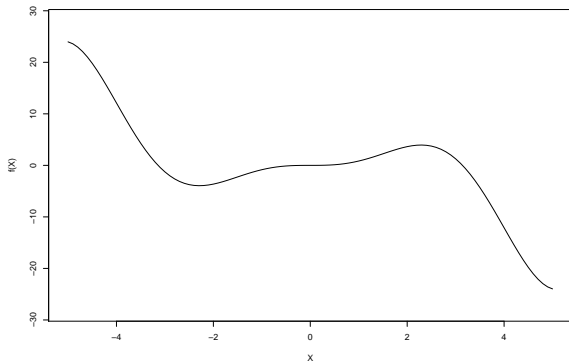
Building a predictive model



Input/output real world data are stored in a database and used to parameterize a predictive model such that it will return a good prediction for new inputs.

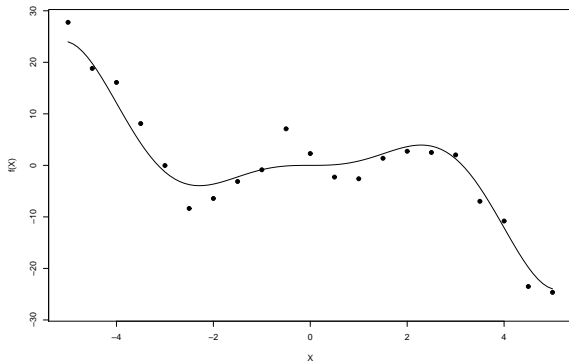
Building a predictive model

Let's suppose we have an unknown input/output function (the phenomenon).



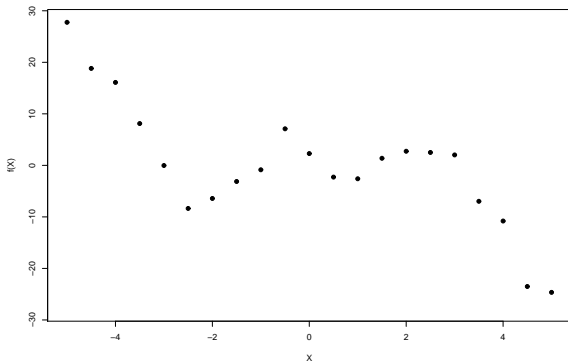
Building a predictive model

Samples with noise are collected from the phenomenon and stored in an database.



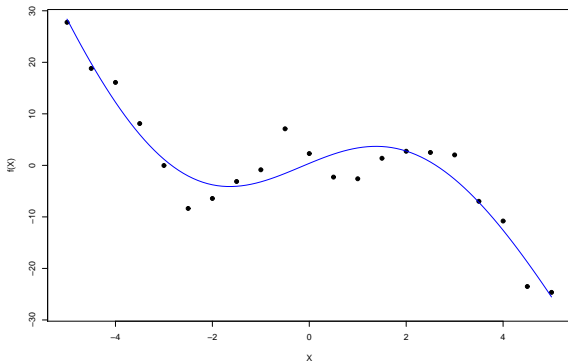
Building a predictive model

The outline of the phenomenon is unknown, thus we have only the samples for building a predictive model.



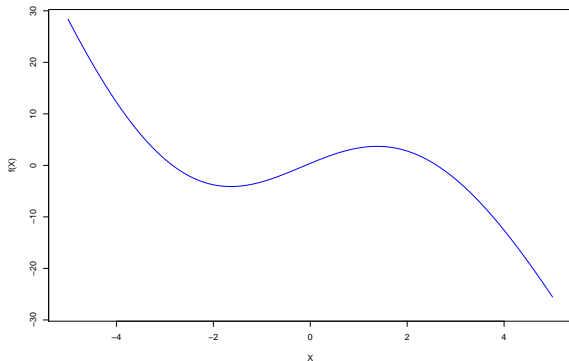
Building a predictive model

Using the information contained in the database, a predictive model is built.



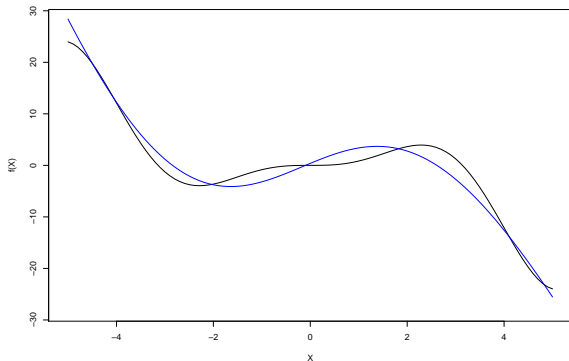
Building a predictive model

The black-box predictive model can be used to predict the outputs of new inputs that are not in the database.



Building a predictive model

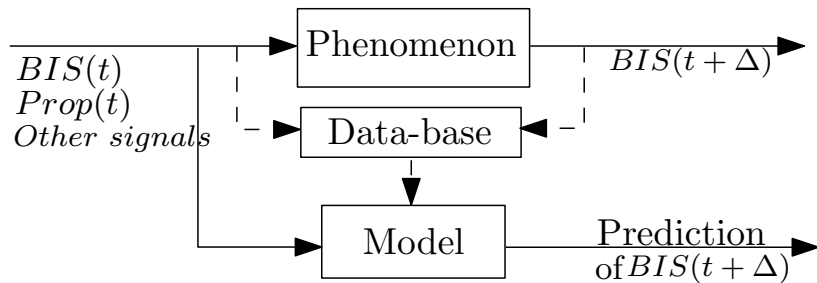
Note that the predictive model (in blue) is an approximation of the real unknown phenomenon (in black).



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 - Sample database
 - Multiple models
 - Variable selection
- 4 Results

Sample database

- 1069 operations in the database.
- 800 to 1800 samples where used by each model.



Multiple models

- To predict the BIS in different time horizons, multiple models have been built.
- Each model specializes in predicting the BIS at a given delay (30 seconds, 1 minute, ...).
- A window of 10 minutes is used in the beginning of the operation to adapt to the inter-patient variability.

Variable selection

- Many variables have been considered.
- The feature selection algorithm selects the best variables considering their predictive power.

age	The patient age.
gender	The patient gender.
height	The patient height (cm).
weight	The patient weight (kg).
lbm	The Lean Body Mass of the patient.
t	The time when the target concentration of propofol is modified (sec).
$B(t)$	The value of the BIS at time t .
$B(t + \Delta t)$	The value of the BIS at time $t + \Delta t$.
$\rho(t)$	The target concentration of propofol before the target modification ($\mu\text{g}/\text{ml}$).
$\Delta\rho(t)$	The modification's magnitude of the propofol target concentration.
$T_p(t)$	The time between the previous modification of propofol and t (sec).
$r(t)$	The target concentration of remifentanil at time t (ng/ml).
$T_r(t)$	The time between the previous modification of remifentanil and t (sec).

Included variables for inter-patient variability

A window of 10 minutes is used in the beginning of the operation to adapt to the inter-patient variability.

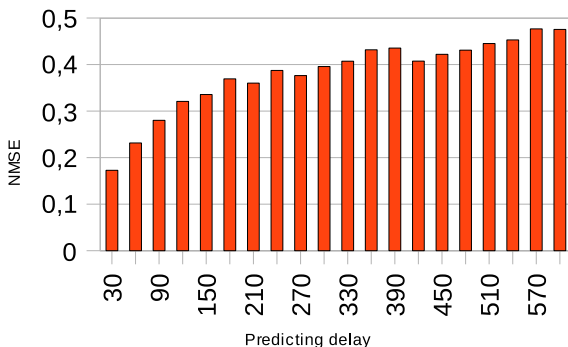
Included variables:

$p80$	The target of propofol when the BIS reaches 80 ($\mu\text{g}/\text{ml}$).
$p70$	The target of propofol when the BIS reaches 70 ($\mu\text{g}/\text{ml}$).
$p60$	The target of propofol when the BIS reaches 60 ($\mu\text{g}/\text{ml}$).
μ_p	The average target concentration of propofol ($\mu\text{g}/\text{ml}$).
μ_r	The average target concentration of remifentaniil (ng/ml).
max_p	The maximum reached by the target of propofol ($\mu\text{g}/\text{ml}$).
$tMax_p$	The instant when max_p is reached (sec).
min_B	The minimum reached by the BIS.
$tMin_B$	The instant when min_B is reached (sec).
R	The ratio between max_p and min_B .

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 - Theoretical results
 - Practical tests

Average error

- The leave-one-out errors are the following.
- Mean Absolute Error is between 3 and 6 on the BIS scale
- Normalized Mean Squared Error is between 0.15 (for shorter delay predictors) and 0.5.

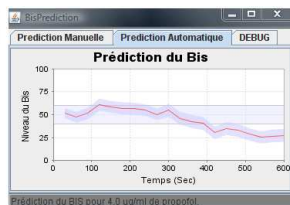


Selected variables

The following variables were selected by the feature selection algorithm for inclusion in the predictive models.

t	The time when the target concentration of propofol is modified (sec).
$p(t)$	The target concentration of propofol before the target modification ($\mu\text{g}/\text{ml}$).
$\Delta p(t)$	The modification's magnitude of the propofol target concentration.
$T_p(t)$	The time between the previous modification of propofol and t (sec).
min_B	The minimum reached by the BIS.
$p70$	The target of propofol when the BIS reaches 70 ($\mu\text{g}/\text{ml}$).
R	The ratio between the maximum reached by the target of propofol and min_B .

Software screenshots



Practical tests and future works

- The software has been used in real cases.
- A thoroughful study must be done to validate the usefulness of the predicting method.

Thank You !