

Segugio; the flexible and efficient tool for reasoning on graphical models

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# Chapter 1

## Fundamental concepts about graphical models

This Section will provide the reader a brief background about the basic concepts in probabilistic graphical models. Moreover, a precise notation will be introduced and used for the rest of this guide. If you are familiar with the basic concepts, just read the following Section.

### 1.1 Preliminaries

Undirect Graphical models are networks made of variables and factors.

In particular, this library is intended for managing categorical variables. Formally, the generic categorical variable  $V$  has a discrete domain  $Dom$ :

$$Dom(V) = \{v_0, \dots, v_n\} \quad (1.1)$$

Essentially,  $Dom(V)$  contains all the possible realizations of  $V$ . The above notation will be adopted for the rest of the guide: indicating with a capital letter the name of a variable, while using the non capital ones for referring to its realizations. Set of categorical variables can be considered also categorical variables, having a domain that is the Cartesian product of the ones of the variables constituting the set. More formally, suppose  $Y$  is obtained considering the set of variables  $X_{1,2,\dots,p}$ , then:

$$Dom(Y) = Dom(X_1) \times Dom(X_2) \times \dots \times Dom(X_p) \quad (1.2)$$

Consequently, a realization of  $v$  of  $V$  is a combination  $\{x_1, \dots, x_p\}$ , i.e. a set of realizations of the variables constituting  $V$ . The following notation will be adopted:

$$V = X_1 \cup \dots \cup X_p = \cup_{i=1}^p X_i \quad (1.3)$$

The entire population of variables contained in a model is a set denoted as  $\mathcal{V} = V_1, \dots, V_m$ . As will be exposed in the following, the joint probability distribution of  $\cup_{V_i \in \mathcal{V}} V_i$  is computed as the factorization of a certain number of components called factors.

In the following, the marginalization concept will be discussed. Such a concept is valid not only for graphical model, but holds for generic set of random variables. Whether the variables in the set  $X_{1,\dots,p}$  (see equation (1.2)) are independent or not, the joint probability distribution of  $X_{1,\dots,p}$  is the probability density of  $V$ . Considering a subset  $SX \subset \{X_1, \dots, X_p\}$ , the probability distribution of  $S = \cup_{X_i \in SX} X_i$  can be obtained through marginalization. Assume  $C = \cup\{\{X_{1,\dots,p}\} \setminus SX\}$ , then it is true that:

$$\mathbb{P}(S = s) = \sum_{\forall \hat{c} \in \{X_{1,\dots,p}\} \setminus SX} \mathbb{P}(S = s, C = \hat{c}) \quad (1.4)$$

The above computation is called marginalization. In a certain sense we are eliminating variables, since we are interested in modelling the probability of a sub set, no matter the realizations of all the other variables.

A factor, sometimes also called a potential, is a positive real function describing the correlation existing among a

	$b_0$	$b_1$	$b_2$	$b_3$	$b_4$
$a_0$	1	4	0	0	0
$a_1$	0	1	0	0	0
$a_2$	0	0	5	0	1

Table 1.1 The values in the codomain of  $\Phi_b(A, B)$ .

$a_0$	$a_1$	$a_2$
0	2	0.5

Table 1.2 The values in the codomain of  $\Phi_u(A)$ .

subset  $X_{1,\dots,p}$  of the variable in  $\mathcal{V}$ . Suppose factor  $\Phi$  involves the set of variables  $\{X, Y, Z\}$ , then  $\Phi(X, Y, Z)$  is a function defined over the domain  $X \cup Y \cup Z$ . More formally:

$$\Phi(X, Y, Z) : \text{DOMAIN}(X) \times \text{DOMAIN}(Y) \times \text{DOMAIN}(Z) \longrightarrow \mathbb{R}^+ \quad (1.5)$$

The aim of  $\Phi$  is to assume 'high' values for those combinations  $\{x, y, z\}$  that are probable and low values (at least a null value) for those being improbable. The entire population of factors is considered for computing  $\mathbb{P}(V_{1,\dots,m})$ , i.e. the joint probability distribution of all the variables in the model. Let be  $\mathcal{D}_i \subset \mathcal{V}$  the subset of variables involved by the  $i^{th}$  factor  $\Phi_i$ . The variable  $D_i$  is the one obtained by merging all variables in  $\mathcal{D}_i$ . The energy function  $E$  of a graph is defined as the product of the factors:

$$E(V_{1,\dots,m}) = \Phi_1(D_1) \cdot \dots \cdot \Phi_p(D_p) = \prod_{i=1}^p \Phi_i(D_i) \quad (1.6)$$

$E$  is addressed for computing the joint probability distribution of the variables in  $\mathcal{V}$ :

$$\mathbb{P}(V_{1,\dots,m}) = \frac{E(V_{1,\dots,m})}{\mathcal{Z}} \quad (1.7)$$

$\mathcal{Z}$  is a normalization coefficient defined as follows:

$$\mathcal{Z} = \sum_{\forall \tilde{V}_{1,\dots,m} \in \text{DOMAIN}(V_1) \times \dots \times \text{DOMAIN}(V_m)} E(\tilde{V}_{1,\dots,m}) \quad (1.8)$$

Although the general theory behind graphical models supports the existence of generic multivaried factors, this library will address only two possible types:

- Binary potentials: they involve a pair of variables.
- Unary potentials: they involve a single variable.

We can store the values in the image of a Binary potential in a two dimensional table. For instance, let be  $\Phi_b$  a binary potential involving two variables  $A$  and  $B$ , whose domains contains 3 and 5 possible values respectively:

$$\begin{aligned} \text{DOM}(A) &= \{a_1, a_2, a_3\} \\ \text{DOM}(B) &= \{b_1, b_2, b_3, b_4, b_5\} \end{aligned} \quad (1.9)$$

The values assumed by  $\Phi_b(A, B)$  are described by table 1.1. Essentially,  $\Phi_b(A, B)$  tells us that the combinations  $\{a_0, b_1\}$ ,  $\{a_2, b_2\}$  are highly probable;  $\{a_0, b_0\}$ ,  $\{a_1, b_1\}$  and  $\{a_2, b_4\}$  are moderately probable. Let be  $\Phi_u(A)$  a Unary potential involving variable  $A$ . The values characterizing  $\Phi_u$  can be stored in a simple vector, see table 1.2. If  $\Phi_b(A, B)$  would be the only potential in the model, the joint probability density of  $A$  and  $B$  will assume the following values <sup>1</sup>:

$$\begin{aligned} \mathbb{P}(a_0, b_1) &= \frac{\Phi_b(a_0, b_1)}{\mathcal{Z}} = \frac{4}{\mathcal{Z}} = 0.3333 \\ \mathbb{P}(a_2, b_2) &= \frac{\Phi_b(a_2, b_2)}{\mathcal{Z}} = \frac{5}{\mathcal{Z}} = 0.4167 \\ \mathbb{P}(a_0, b_0) &= \frac{\Phi_b(a_0, b_0)}{\mathcal{Z}} = \mathbb{P}(a_1, b_1) = \mathbb{P}(a_2, b_4) = \frac{1}{\mathcal{Z}} = 0.0833 \end{aligned} \quad (1.10)$$

<sup>1</sup>combinations having a null probability were omitted



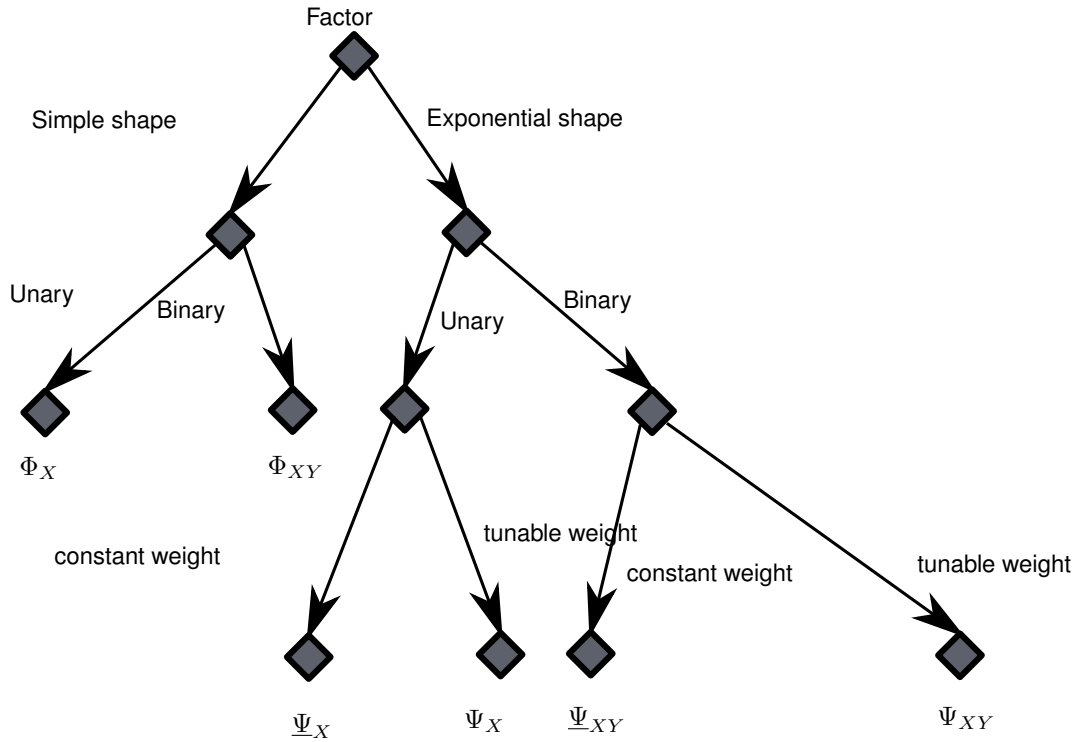


Figure 1.1 All the possible categories of factors, with the corresponding notation.

since  $\mathcal{Z}$  is equal to:

$$\mathcal{Z} = \sum_{\forall i=0,1,2, \forall j=0,1,2,3,4} \Phi_b(A = a_i, B = b_j) = 12 \quad (1.11)$$

Both Unary and Binary potentials, can be of two possible classes:

- Simple shape. The potential is simply described by a set of values characterizing the image of the factor.  $\Phi_b(A, B)$  and  $\Phi_u(A)$  of the previous example are both Simple shapes.
- Exponential shape. This kind of factors are indicated with  $\Psi_i$  and their image set is defined as follows:

$$\Psi_i(X) = \exp(w \cdot \Phi_i(X)) \quad (1.12)$$

where  $\Phi_i$  is a Simple shape. The weight  $w$ , can be tunable or not. In the first case,  $w$  is a free parameter whose value is decided after training the model (see Section 1.6), otherwise is a constant. Exponential shapes with fixed weight will be denoted with  $\bar{\Psi}_i$ .

Figure 1.1 resumes all the possible categories of factors that can be present in the models handled by this library.

Figure 1.2 reports an example of undirected graph. Set  $\mathcal{V}$  is made of 4 variables:  $A, B, C, D$ . There are 5 Binary potentials and 2 Unary ones. The graphical notation adopted for Fig. 1.2 will be adopted for the rest of this guide. Weights  $\alpha, \beta, \gamma$  and  $\delta$  are assumed for respectively  $\Psi_{AC}, \Psi_{AB}, \Psi_{CD}, \Psi_B$ . For the sake of clarity, the joint probability of the variables in Fig. 1.2 is computable as follows:

$$\begin{aligned} \mathbb{P}(A, B, C, D) &= \frac{E(A, B, C, D)}{\mathcal{Z}(\alpha, \beta, \gamma, \delta)} \\ E(A, B, C, D) &= \Phi_A(A) \cdot \exp(\alpha \Phi_{AC}(A, C)) \cdot \exp(\beta \Phi_{AB}(A, B)) \cdots \\ &\cdots \Phi_{BC}(B, C) \cdot \exp(\gamma \Phi_{CD}(C, D)) \cdot \Phi_{BD}(B, D) \cdot \exp(\delta \Phi_B(B)) \end{aligned} \quad (1.13)$$

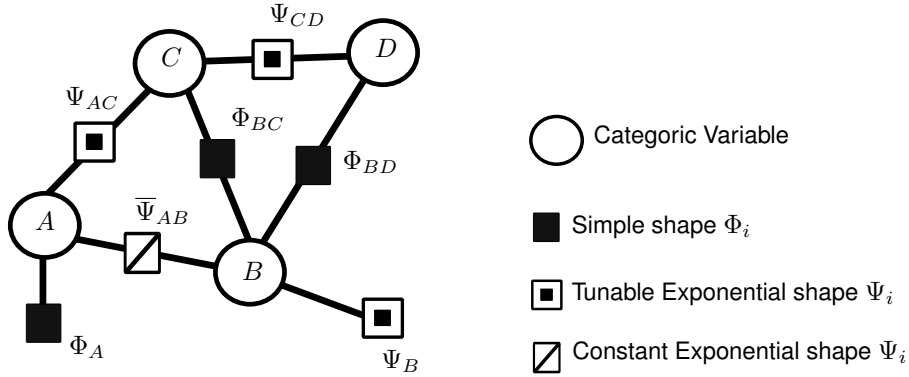


Figure 1.2 Example of graph: the legend of the right applies.

Graphical models are mainly used for performing belief propagation. Subset  $\mathcal{O} = O_1, \dots, O_f \subset \mathcal{V}$  is adopted for denoting the set of evidences: those variables in the net whose value become known.  $\mathcal{O}$  can be dynamical or not. The hidden variables are contained in the complementary set  $\mathcal{H} = H_1, \dots, H_t$ . Clearly  $\mathcal{O} \cup \mathcal{H} = \mathcal{V}$  and  $\mathcal{O} \cap \mathcal{H} = \emptyset$ .  $H$  will be the variable obtained merging all the  $H_1, \dots, H_t$ , while  $O$  is similar defined considering  $O_1, \dots, O_f$ . Knowing the joint probability distribution of variables in  $\mathcal{V}$  (equation (1.7)) the conditional distribution of  $H$  w.r.t.  $O$  can be determined as follows:

$$\begin{aligned} \mathbb{P}(H = h | O = o) &= \frac{\mathbb{P}(H = h, O = o)}{\sum_{\hat{h} \in \text{Dom}(H)} \mathbb{P}(H = \hat{h}, O = o)} \\ &= \frac{E(h, o)}{\sum_{\hat{h} \in \text{Dom}(H)} E(\hat{h}, o)} = \frac{E(h, o)}{\mathcal{Z}(o)} \end{aligned} \quad (1.14)$$

The above computations are not actually done, since the number of combinations in the domain of  $\mathcal{H}$  is huge also when considering a low-medium size graph. On the opposite, the marginal probability  $\mathbb{P}(H_i = h_i | O = 0)$  of a single variable in  $H_i \in \mathcal{H}$  is computationally tractable. Formally  $\mathbb{P}(H_i = h_i | O = 0)$  is defined as follows:

$$\mathbb{P}(H_i = h_i | O = o) = \sum_{y \in \{\mathcal{H} \setminus H_i\}} \mathbb{P}(H_i = h_i, y | O = o) \quad (1.15)$$

The above marginal distribution is essentially the conditional distribution of  $H_i$  w.r.t.  $O$ , no matter the other variables in  $\mathcal{H}$ .

A generic Random Field is a graphical model for which set  $\mathcal{O}$  (and consequently  $\mathcal{H}$ ) is dynamical: the set of observations as well the values assumed by the evidences may change during time. Random field are handled by class `Random_Field` 5.39. Conditional Random Field are Random Field for which set  $\mathcal{O}$  must be decided once and cannot change after. Only the values of the evidences during time may change. Class `Conditional_Random_Field` 5.11 is in charge of handling Conditional Random Field. Both Random Fields and Conditional Random Fields can be learnt knowing a training set, see Section 1.6. On the opposite class `Graph` 5.18 handles constant graphs: they are conceptually similar to Random Fields but learning is not possible. Indeed, all the Exponential Shape involved must be constant.

The rest of this Chapter is structured as follows. Section 1.2 will introduce the message passing algorithm, which is the pillar for performing belief propagation. Section 1.3 will expose the concept of maximum a posteriori estimation, useful when querying a graph, while Section 1.4 will address Gibbs sampling for producing a training set of a known model. Section 1.5 will present the concept of subgraph which is a useful way for computing the marginal probabilities of a sub group of variables in  $\mathcal{H}$ . Finally 1.6 will discuss how the learning of a graphical model is done, with the aim of computing the weights of the Exponential shapes that are tunable.

## 1.2 Message Passing

Message passing is a powerful but conceptually simple algorithm adopted for propagating the belief across a net. Such a propagation is the starting point for performing many important operations, like computing the marginal distributions of single variables or obtaining sub graphs. Before detailing the steps involved in the message passing algorithm, let's start from an example of belief propagation.

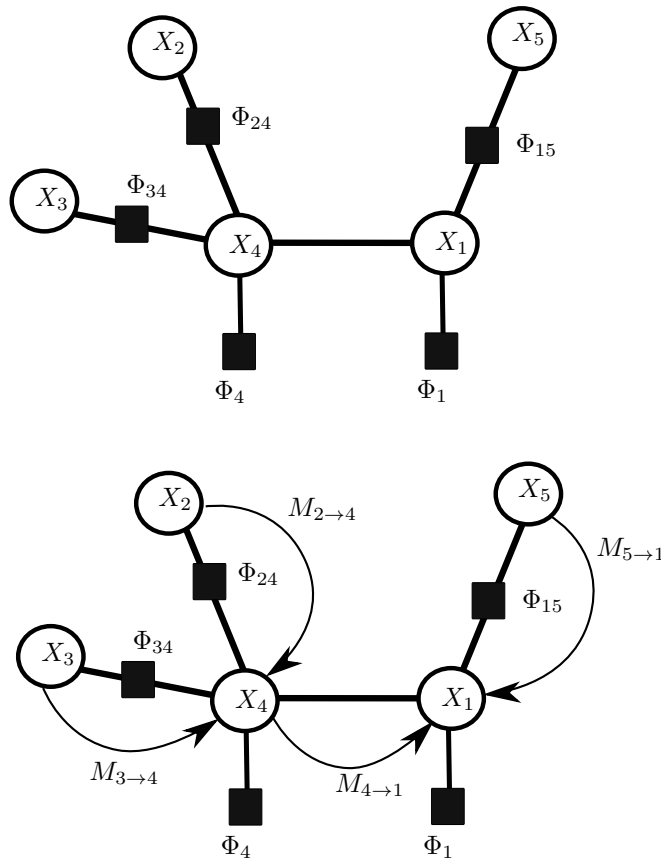


Figure 1.3 Example of graph adopted for explaining the message passing algorithm. Below are reported the messages to compute for obtaining the marginal probability of variable  $x_1$

### 1.2.1 Belief propagation

Consider the graph reported in <sup>2</sup> Figure 1.3. Supposing for the sake of simplicity that no evidences are available (i.e.  $\mathcal{O} = \emptyset$ ), we are interested in computing  $\mathbb{P}(X_1)$ , the marginal probability of variable  $X_1$ . Recalling the definition introduced in the previous Section, the marginal probability is obtained by the following computation:

$$\mathbb{P}(x_1) = \sum_{\forall \tilde{x}_{2,3,4,5} \in \cup_{i=\{2,3,4,5\}} X_i} \mathbb{P}(x_1, \tilde{x}_{2,3,4,5}) \quad (1.16)$$

Simplifying the notation and getting rid of the normalization coefficient  $\mathcal{Z}$  we can state the following:

$$\mathbb{P}(x_1) \propto \sum_{\tilde{x}_{2,3,4,5}} E(x_1, \tilde{x}_{2,3,4,5}) \quad (1.17)$$

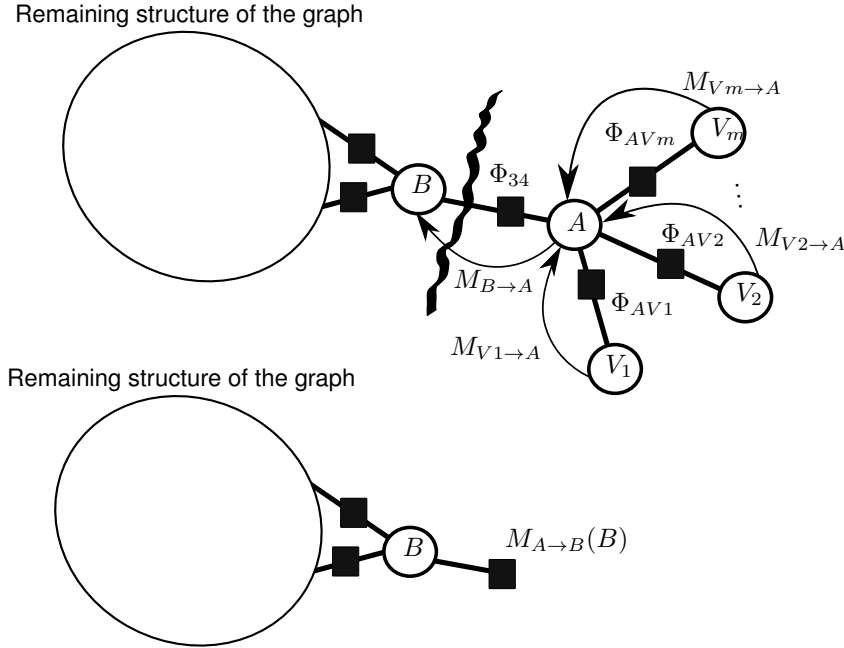
Adopting the algebraic properties of the sums-products we can distribute the computations as follows:

$$\mathbb{P}(x_1) \propto \Phi_1(x_1) \sum_{\tilde{x}_5} \Phi_{15}(x_1, \tilde{x}_5) \sum_{\tilde{x}_4} \Phi_{14}(x_1, \tilde{x}_4) \Phi_4(\tilde{x}_4) \sum_{\tilde{x}_2} \Phi_{24}(\tilde{x}_2, \tilde{x}_4) \sum_{\tilde{x}_3} \Phi_{34}(\tilde{x}_3, \tilde{x}_4) \quad (1.18)$$

The first variable to marginalize can be  $\tilde{x}_2$  or  $\tilde{x}_3$ , since they are involved in the last terms of the sums products, which will be called messages. Messages  $M_{2 \rightarrow 4}$ ,  $M_{3 \rightarrow 4}$  are defined as follows:

$$\begin{aligned} M_{2 \rightarrow 4}(\tilde{x}_4) &= \sum_{\tilde{x}_2} \Phi_{24}(\tilde{x}_2, \tilde{x}_4) \\ M_{3 \rightarrow 4}(\tilde{x}_4) &= \sum_{\tilde{x}_3} \Phi_{34}(\tilde{x}_3, \tilde{x}_4) \end{aligned} \quad (1.19)$$

<sup>2</sup>Without loss of generality we assumed all the factors as simple shapes



**Figure 1.4** On the top the general mechanism involved in the message computation; on the bottom the simplification of the graph considering the computed message.

Inserting  $M_{2 \rightarrow 4}$  and  $M_{3 \rightarrow 4}$  into equation (1.20) leads to:

$$\mathbb{P}(x_1) \propto \Phi_1(x_1) \sum_{\tilde{x}_5} \Phi_{15}(x_1, \tilde{x}_5) \sum_{\tilde{x}_4} \Phi_{14}(x_1, \tilde{x}_4) \Phi_4(\tilde{x}_4) M_{2 \rightarrow 4}(\tilde{x}_4) M_{3 \rightarrow 4}(\tilde{x}_4) \quad (1.20)$$

At this point the messages  $M_{4 \rightarrow 1}$  and  $M_{5 \rightarrow 1}$  can be computed in the following way:

$$\begin{aligned} M_{4 \rightarrow 1}(x_1) &= \sum_{\tilde{x}_4} \Phi_{14}(x_1, \tilde{x}_4) \Phi_4(\tilde{x}_4) M_{2 \rightarrow 4}(\tilde{x}_4) M_{3 \rightarrow 4}(\tilde{x}_4) \\ M_{5 \rightarrow 1}(x_1) &= \sum_{\tilde{x}_5} \Phi_{15}(x_1, \tilde{x}_5) \end{aligned} \quad (1.21)$$

After inserting  $M_{4 \rightarrow 1}$  and  $M_{5 \rightarrow 1}$  into equation (1.20) we obtain:

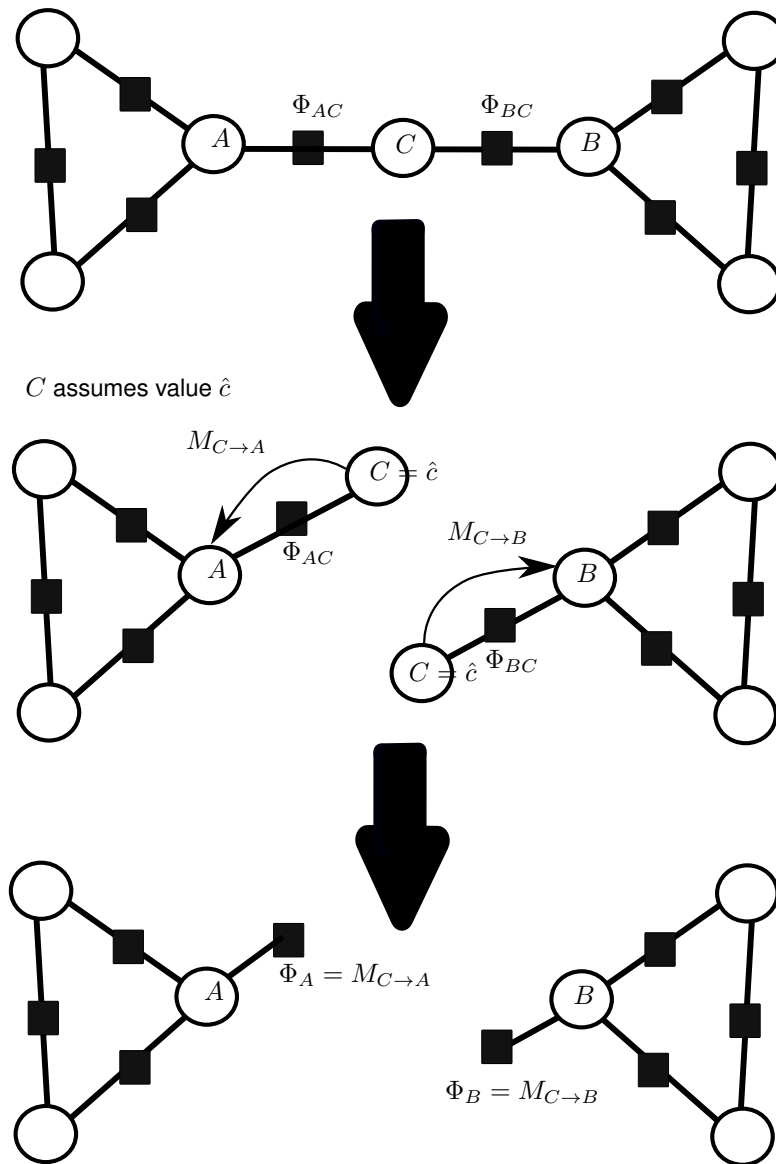
$$\mathbb{P}(x_1) \propto \Phi_1(x_1) M_{4 \rightarrow 1}(x_1) M_{5 \rightarrow 1}(x_1) \quad (1.22)$$

which ends the computations. Messages are, in a certain sense, able to simplify the graph sending some information from an area of the graph to another one. Indeed, it's like eliminating the variables for replacing it with messages, to be treated as additional factors. Figure 1.3 resumes the computations exposed. Notice that the computation of  $M_{4 \rightarrow 1}$  must be done after computing the messages  $M_{2 \rightarrow 4}$  and  $M_{3 \rightarrow 4}$ , while  $M_{5 \rightarrow 1}$  can be computed independently from all the others.

The aforementioned considerations can be extended to a general structured graph. Look at Figure 1.4: the computation of Message  $M_{B \rightarrow A}$  can be performed only after having computed all the messages  $M_{V_1, \dots, m \rightarrow B}$ , i.e. the messages incoming from all the neighbours of  $B$  a part from  $A$ . Clearly  $M_{B \rightarrow A}$  is computed as follows:

$$M_{B \rightarrow A}(a) = \sum_{\tilde{b}} \Phi_{AB}(a, \tilde{b}) M_{V_1 \rightarrow B}(\tilde{b}) \cdots M_{V_m \rightarrow B}(\tilde{b}) \quad (1.23)$$

Essentially, it's like having simplified the graph: we can append to  $B$  the message  $M_{B \rightarrow A}(b)$  as it's a Simple shape, deleting factor  $\Phi_{AB}$  and all the other portions of the graph, see Figure 1.4. In turn,  $M_{B \rightarrow A}(b)$  will be adopted for computing the message outgoing from  $B$ . The above elimination is not actually done: all messages incoming to all nodes of a graph are computed by a derivation of 5.21 and are stored to be used for subsequent queries. This is partially not true when considering the evidences. Indeed, when the values of the evidences are retrieved, variables in  $\mathcal{O}$  are temporary deleted and replaced with messages, see Figure 1.5. Suppose variable  $C$  is connected to a



**Figure 1.5** When variable C become an evidence, is temporary deleted from the graph, replaced by messages.

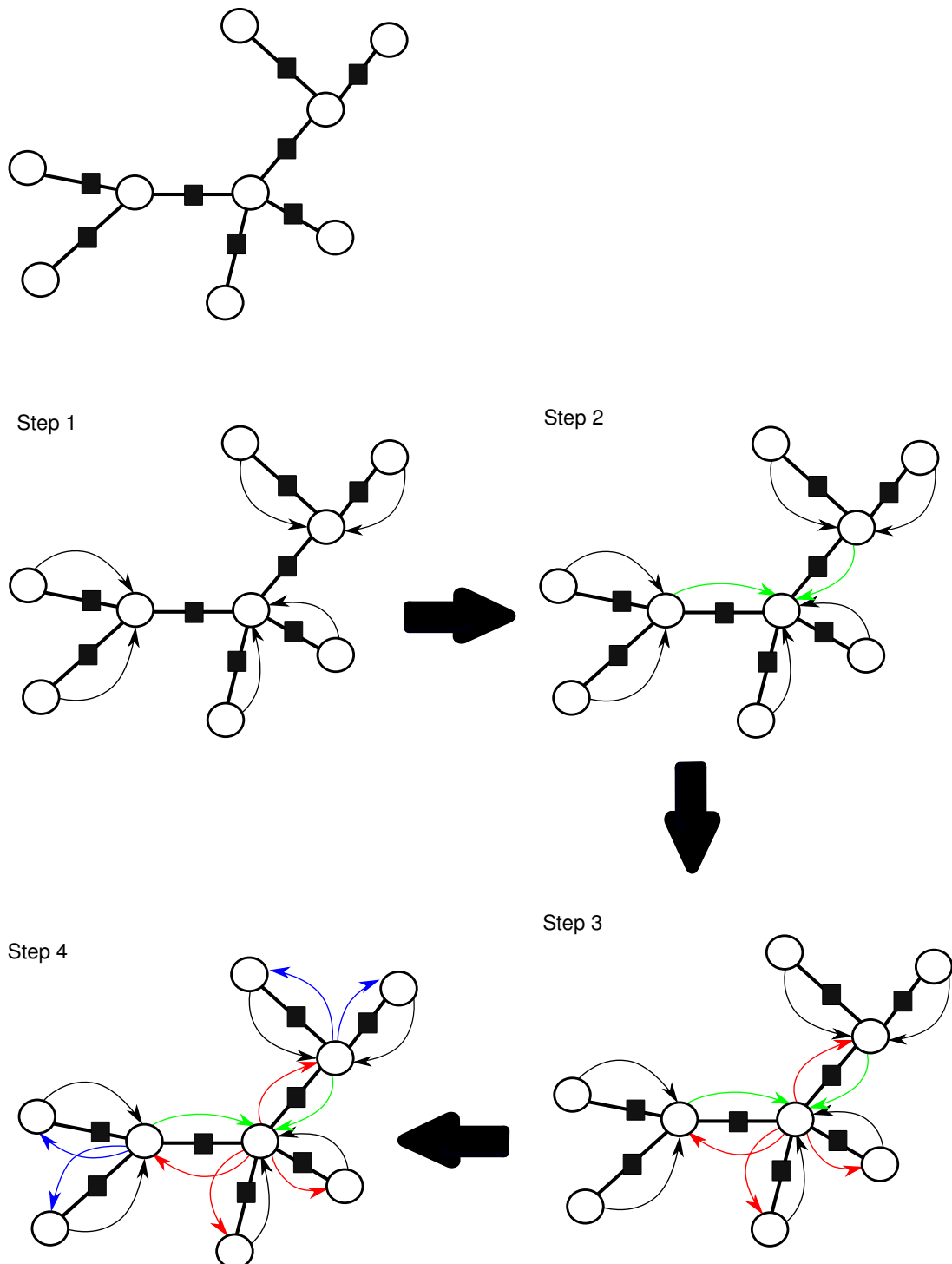
variable  $A$  through a binary potential  $\Phi_{AC}(A, C)$  and to variable  $B$  through  $\Phi_{BC}$ . Suppose also that variable  $C$  assumes a value equal to  $\hat{c}$ , then the messages sent to  $A$  and  $B$  can be computed independently as follows:

$$\begin{aligned} M_{C \rightarrow A}(a) &= \Phi_{AC}(a, \hat{c}) \\ M_{C \rightarrow B}(b) &= \Phi_{BC}(b, \hat{c}) \end{aligned} \tag{1.24}$$

Therefore all the variables that become evidences can be considered as a leaves of the graph sending messages to all the neighbouring nodes, possibly splitting an initial compact graph into many subgraphs refer to Figure 1.5. Such computations are automatically handled by the library.

All the above considerations are valid when considering politree, i.e. graph without loops. Indeed for these kind of graphs the message passing algorithm is able in a finite number of iterations to compute all the messages, see Figure 1.6. The same is not true when having loopy graphs, see Figure 1.7 since deadlocking situations are reached: no further messages can be computed since for every nodes some incoming ones are missing. In such cases a variant of the message passing called loopy belief propagation can be adopted. Loopy belief propagation initializes all the messages to basic shapes having the values of the image all equal to 1 and then recomputes all the messages of all the variables till convergence.

You don't have to handle the latter aspect: when a belief propagation is performed, the library automatically choose to deploy 5.32 or 5.30, according to the structure of the graph for which the propagation is asked.



**Figure 1.6** Steps involved for computing the messages of the politree represented at the top. The leaves are the first nodes for which the outgoing messages can be computed.

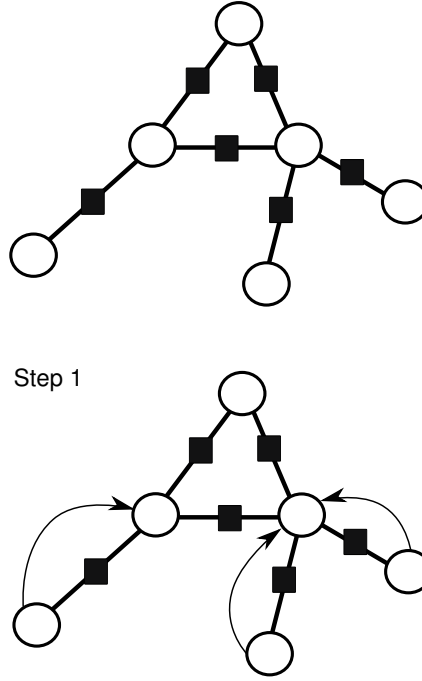


Figure 1.7 Steps involved for computing the messages on a loopy graph: after computing the messages outgoing from the leaves, a deadlock is reached since no further messages are computable.

### 1.3 Maximum a posteriori estimation

Suppose we are not interested in determining the marginal probability of a specific variable, but rather we want the combination in the hidden set  $\mathcal{H}$  that maximises the probability  $\mathbb{P}(H_1, \dots, H_n | O)$ . Clearly, we could try to compute the entire distribution  $\mathbb{P}(H_1, \dots, H_n | O)$  and then take the value of  $H$  maximising that distribution. However, this is not computationally possible since even for low medium size graphs the size of  $\text{Dom}(\cup_{H_i \in \mathcal{H}} H_i)$  can be huge.

Maximum a posteriori estimations solve this problem: the value maximising  $\mathbb{P}(H_1, \dots, H_n | O)$  is computed, without explicitly building the entire distribution  $\mathbb{P}(H_1, \dots, H_n | O)$ . This is achieved by performing belief propagation with a slightly different version of the message passing algorithm (see Section 1.2). Indeed, referring to Figure 1.4, the message to  $A$  is computed as follows when performing a maximum a posteriori estimation:

$$M_{B \rightarrow A}(a) = \max_{\tilde{b}} \{ \Phi_{AB}(a, \tilde{b}) M_{V1 \rightarrow B}(\tilde{b}) \cdots M_{Vm \rightarrow B}(\tilde{b}) \} \quad (1.25)$$

Essentially the summation in equation (1.23) is replaced with the max operator. After all messages are computed, the estimation  $h_{MAP} = \{h_{1MAP}, h_{2MAP}, \dots\}$  is obtained by considering for every variable in  $\mathcal{H}$  those value maximising

$$h_{iMAP} = \text{ARGMAX} \{ \Phi_{H_i}(h_{iMAP}) M_1(h_{iMAP}) \cdots M_L(h_{iMAP}) \} \quad (1.26)$$

where  $M_1, \dots, M_L$  refer to all the messages incoming to the generic variable in  $H_i$ . To be precise, this procedure is not guaranteed to return the value actually maximising  $\mathbb{P}(H_1, \dots, H_n | O)$ , but at least a strong local maximum is obtained. At this point it is worthy to clarify that the combination  $h_{MAP} = \{h_{1MAP}, h_{2MAP}, \dots\}$  could not be obtained by simply assuming for every  $H_i$  the realization maximising the marginal distribution:

$$h_{MAP} \neq \{ \text{argmax}(\mathbb{P}(h_1)), \dots, \text{argmax}(\mathbb{P}(h_n)) \} \quad (1.27)$$

This is due to the fact that  $\mathbb{P}(H_1, \dots, H_n | O)$  is a joint probability distribution, while the marginals  $\mathbb{P}(H_i)$  are not. For better understanding this aspect consider the graph reported in Figure 1.8, with the potentials  $\Phi_{XA}$ ,  $\Phi_{AB}$  and  $\Phi_{YB}$  having the images defined in table 1.3. Suppose discovering that  $X = 0$  and  $Y = 1$ . Then, performing the standard message passing algorithm explained in the previous Section we obtain the messages reported in Figure 1.8. Clearly individual marginals for  $A$  and  $B$  would be equal to:

$$\begin{aligned} \mathbb{P}(A) &= \begin{pmatrix} \mathbb{P}(A = 0) \\ \mathbb{P}(A = 1) \end{pmatrix} = \begin{pmatrix} 0.5 \\ 0.5 \end{pmatrix} \\ \mathbb{P}(B) &= \begin{pmatrix} \mathbb{P}(B = 0) \\ \mathbb{P}(B = 1) \end{pmatrix} = \begin{pmatrix} 0.5 \\ 0.5 \end{pmatrix} \end{aligned} \quad (1.28)$$

	$b_0$	$b_1$		$x_0$	$x_1$		$y_0$	$y_1$
$a_0$	2	0	$a_0$	1	0.1	$b_0$	1	0.1
$a_1$	0	2	$a_1$	0.1	1	$b_1$	0.1	1

Table 1.3 Factors involved in the graph of Figure 1.8.

$A$	$B$	$E(A, B, X = 0, Y = 1)$
0	0	0.2
0	1	0
1	0	0
1	1	0.2

Table 1.4 Factors involved in the graph of Figure 1.8.

Therefore, all the combinations  $\{A = 0, B = 0\}$ ,  $\{A = 0, B = 1\}$ ,  $\{A = 1, B = 0\}$ ,  $\{A = 1, B = 1\}$  maximise  $\mathbb{P}(A, B|O)$ . However, it easy to prove that  $E(A, B, X, Y)$  assumes the values reported in table 1.4. Therefore, the combinations actually maximising the joint distribution  $\mathbb{P}(A, B|O)$  are  $\{A = 0, B = 0\}$  and  $\{A = 1, B = 1\}$ , leading to a different result.

Maximum a posteriori estimation can be performing invoking `MAP_on_Hidden_set` 5.35.2.6 on a particular derivation of class 5.35. Maximum a posteriori estimation for sub graphs (see Section 1.5) is also supported by method `MAP` 5.3.2.3.

## 1.4 Gibbs sampling

Gibbs sampling is a Monte Carlo method for obtaining samples from a joint distribution of variables  $X_1, \dots, m$ , without explicitly compute that distribution. Indeed, Gibbs sampling is an iterative method which requires every time to determine the conditional distribution of a single variable  $X_i$  w.r.t to all the others in the group.

More formally the algorithm starts with an initial combination of values  $\{x_1^1, \dots, m\}$  for the variable  $\cup_{i=\{1, \dots, m\}} X_i$ . At every iteration, all the values of that combination are recomputed. At the  $j^{th}$  iteration the value of  $x_k^{j+1}$  for the subsequent iteration is obtaining by sampling from the following marginal distribution:

$$x_k^{j+1} \sim \mathbb{P}(x_k | x_{\{1, \dots, m\} \setminus k}^j) \quad (1.29)$$

After an initial transient, the samples cumulated during the iterations can be considered as drawn from the joint distribution involving group  $X_1, \dots, m$ .

This algorithm can be easily applied to graphical model. Indeed the methodologies exposed in Section 1.2 can be applied for determining the conditional distribution of a single variable  $H_i \in \mathcal{H}$  w.r.t all the others (as well the evidences in  $\mathcal{O}$ ), assuming all variables in  $\mathcal{H} \setminus H_i$  as additional observations and computing the marginal probability of  $H_i$ . `Gibbs_Sampling_on_Hidden_set` 5.35.2.5 is in charge of performing Gibbs sampling on a generic graph, while method `Gibbs_Sampling` 5.3.2.2 performs the same for sub graphs (see 1.5).

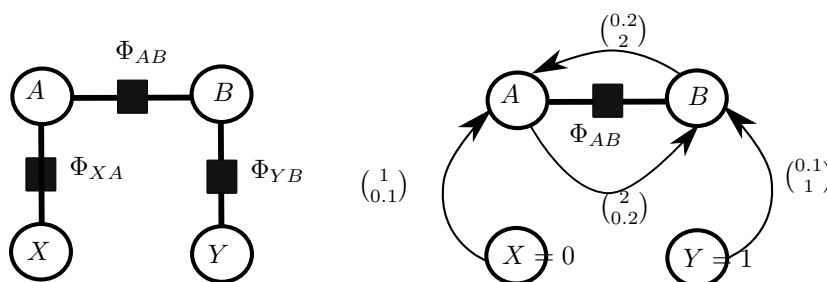


Figure 1.8 Example of graph adopted. When the evidences are retrieved, the messages computed by making use of the message passing algorithm are reported below.



## 1.5 Sub graphs

As explained in Section 1.2, the marginal probability of a variable  $H_i \in \mathcal{H}$  can be efficiently computed by considering the messages produced by the message passing algorithm. The same messages can be also used for performing graph reduction, with the aim to model the joint probability distribution of a subset of variables  $\{H_1, H_2, H_3\} \subset \mathcal{H}$ , i.e.  $\mathbb{P}(H_{1,2,3}|O)$ . The latter quantity is the marginal probability of the subset of variables of interest.

Since the aim of message passing is essentially to simplify the graph, condensing all the belief information into the messages, it is possible to compute sub graphs. Without loss of generality assume from now on  $O = \emptyset$ . Consider the graph in Figure 1.9 and suppose we are interested in modelling  $\mathbb{P}(A, B, C)$ , no matter the values of the other variables. After computing all the messages exploiting message passage, the sub graph reported in Figure 1.9 is the one modelling  $\mathbb{P}(A, B, C)$ . Actually, that sub graph is a graphical model itself, for which all the properties exposed so far hold. For example the energy function  $E$  is computable as follows:

$$E(A = a, B = b, C = c) = \Phi_{AB}(a, b)\Phi_{BC}(b, c)\Phi_{AC}(a, c)M_{X \rightarrow A}(a)M_{Y \rightarrow B}(b) \quad (1.30)$$

while the joint probability of  $A, B$  and  $C$  can be computed in this way:

$$\mathbb{P}(A = a, B = b, C = c) = \frac{E(a, b, c)}{\sum_{\forall \tilde{a}, \tilde{b}, \tilde{c}} E(\tilde{a}, \tilde{b}, \tilde{c})} \quad (1.31)$$

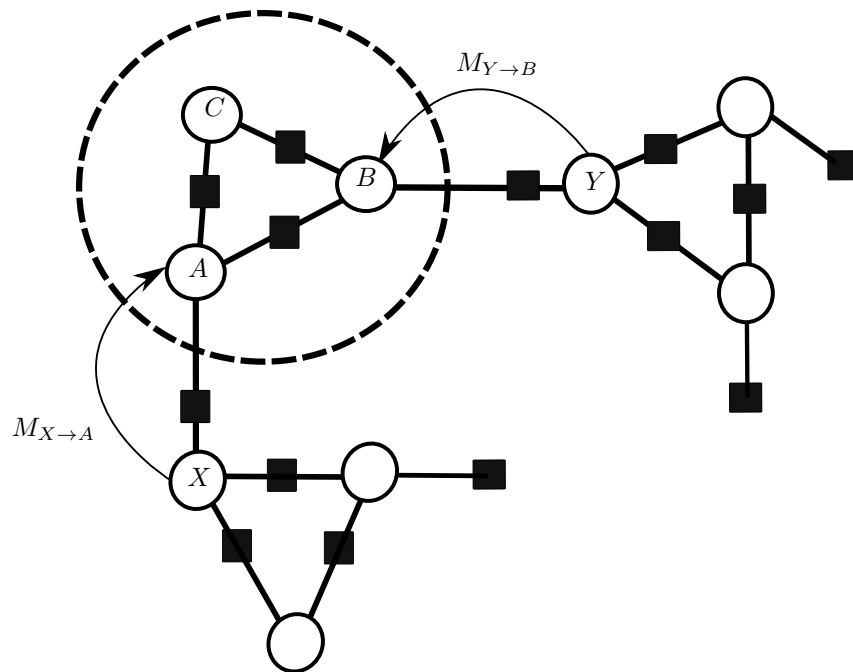
Notice that in this case the graph is significantly smaller than the originating one, implying that the above relation is computationally possible.

Also Gibbs sampling can be applied to a reduced graph, producing samples drawn from the marginal probability  $\mathbb{P}(A, B, C)$ .

The reduction described so far is always possible when considering a subset of variables forming a connected subportion of the original graph, i.e. after reduction there must be a unique sub structure. For instance, variables  $X$  and  $Y$  of the graph in Figure 1.10 do not respect the latter specification, meaning that it is not possible to build a sub graph involving  $X$  and  $Y$ .

The class in charge of handling graph reduction is 5.3.

## 1.6 Learning



Sub graph involving  $A, B, C$

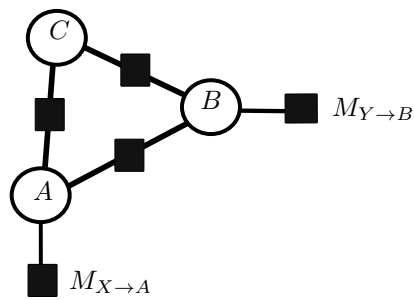


Figure 1.9 Example of graph reduction.

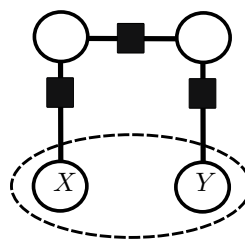


Figure 1.10 Example of a subset of variables for which the graph reduction is not possible.

## Chapter 2

# XML notation

The aim of this Section is to expose how to build graphical models from XML files describing their structures. In particular, the syntax of such an XML will be clarified. XML files can be passed as input for the constructor of Graph [5.18.2.2](#), Random\_Field [5.39.2.2](#) and Conditional\_Random\_Field [5.11.2.1](#). Figure [2.1](#) visually explains the structure of a valid XML.

Essentially two kind of tags must be incorporated:

- Variable: describes the information related to a variable present in the graph. There must a tag of this kind for every variable constituting the model. Fields description:
  - name: is a string indicating the name of this variable.
  - Size: is the size of the variable, i.e. the size of  $Dom$ , see Section [1.1](#).
  - flag[optional] : is a flag that can assume two possible values, 'O' or 'H' according to the fact that this variable is in set  $\mathcal{O}$  (Section [1.1](#)) or not respectively. When non specifying this flag 'H' is assumed.
- Potential: describes the information related to a unary or a binary potential present in the graph (see Section [1.1](#)). Fields description:
  - var: the name of the first variable involved.
  - var[optional]: the name of the second variable involved. Is omitted when considering unary potentials, while is mandatory when a binary potentials is described by this tag.
  - weight[optional]: when specifying an Exponential shape (Section [1.1](#)) it must be present for indicating the value of the weight  $w$  (equation [\(1.12\)](#)). When omitting, the potential is assumed as a Simple shape one.
  - tunability[optional]: it is a flag for specifying whether the weight of this Exponential shape is tunable or not (see Section [1.1](#)). Is ignored in case weight is omitted. It can assumes two possible values, 'Y' or 'N' according to the fact that the weight involved is tunable or not respectively. When weight is specified and tunability is omitted, a value equal to 'Y' is assumed.

The following components are exclusive: only one of them can be specified in a Potential tag and at the same time at least one must be present.

- Correlation: it can assume two possible values, 'T' or 'F'. When 'T' is passed, this potential is assumed to be a simple shape correlating shape (see [5.38.2.3](#)), otherwise when passing 'F' a simple anti correlating shape is assumed (see [5.38.2.3](#)). It is invalid in case this Potential is a unary one. In case weight was specified, an Exponential shape is built, wrapping a simple correlating or anti-correlating shape.
- Source: it is the location of a textual file describing the values of the distribution characterizing this potential. Rows of this file contain the values charactering the image of the potential. Combinations not specified are assumed to have an image value equal to 0. Clearly the number of values charactering the distribution must be consistent with the number of specified var fields. In case weight was specified, an Exponential shape is built, wrapping the Simple shape whose values are specified in the aforementioned

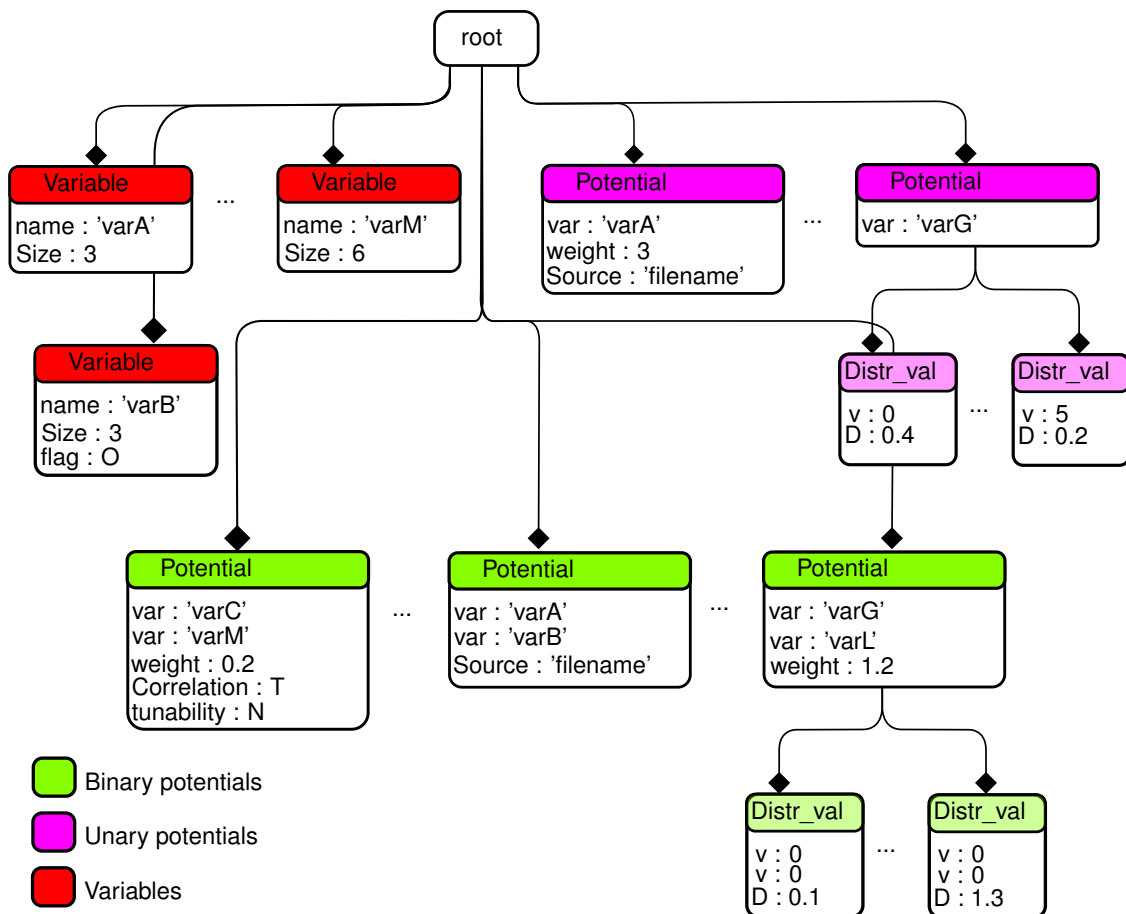


Figure 2.1 The structure of the XML describing a graphical model.

file. For instance, the potential  $\Phi_b$  of Section 1.1 would have been described by a file containing the following rows:

```

0 0 1
0 1 4
1 1 1
2 2 5
2 4 1

```

- Set of sub tags `Distr_val`: is a set of nested tags describing the distribution of the this potential. Similarly to `Source`, every element use fields `v` for describing the combination, while `D` is used for specifying the value assumed by the distribution. For example the potential  $\Phi_b$  of Section 1.1 would have been described by the syntax reported in Figure 2.2. In case `weight` was specified, an Exponential shape is built, wrapping the Simple shape whose distribution is specified by the aforementioned sub tags.

```
<Potential ...>  
  <Distr_val "v"=0 "v"=0 "D"=1>  
  <Distr_val "v"=0 "v"=1 "D"=4>  
  <Distr_val "v"=1 "v"=1 "D"=1>  
  <Distr_val "v"=2 "v"=2 "D"=5>  
  <Distr_val "v"=2 "v"=4 "D"=1>  
</Potential>
```

**Figure 2.2 Syntax to adopt for describing the potential  $\Phi_b$  of Section 1.1, using a population of Distr\_val sub tags.**



## Chapter 3

# Hierarchical Index

### 3.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Segugio::Node::Node_factory::_Pot_wrapper_4_Insertion . . . . .	21
Segugio::Node::Node_factory::_Baseline_4_Insertion< T > . . . . .	21
Segugio::Node::Node_factory::_SubGraph . . . . .	22
Segugio::Categoric_var . . . . .	27
Segugio::Categoric_domain . . . . .	27
Segugio::I_Potential::Getter_4_Decorator . . . . .	33
Segugio::I_Potential_Decorator< I_Potential > . . . . .	43
Segugio::Potential . . . . .	55
Segugio::Message_Unary . . . . .	47
Segugio::I_Potential_Decorator< Potential_Exp_Shape > . . . . .	43
Segugio::I_Learning_handler . . . . .	40
Segugio::Binary_handler . . . . .	26
Segugio::Binary_handler_with_Observation . . . . .	26
Segugio::Unary_handler . . . . .	70
Segugio::I_Potential_Decorator< Potential_Shape > . . . . .	43
Segugio::Potential_Exp_Shape . . . . .	57
Segugio::I_Potential_Decorator< Wrapped_Type > . . . . .	43
Segugio::Potential_Exp_Shape::Getter_weight_and_shape . . . . .	33
Segugio::I_Learning_handler . . . . .	40
Segugio::Training_set::subset::Handler . . . . .	37
Segugio::Trainer_Decorator . . . . .	68
Segugio::Entire_Set . . . . .	32
Segugio::Stoch_Set_variation . . . . .	66
Segugio::I_belief_propagation_strategy . . . . .	38
Segugio::Loopy_belief_propagation . . . . .	46
Segugio::Message_Passing . . . . .	49
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Segugio::Training_set::I_Extractor< Array > . . . . .	39
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Segugio::I_Potential_Decorator< Potential_Exp_Shape > . . . . .	43
Segugio::I_Potential_Decorator< Potential_Shape > . . . . .	43
Segugio::I_Potential_Decorator< Wrapped_Type > . . . . .	43
Segugio::Potential_Shape . . . . .	60
Segugio::I_Trainer . . . . .	44
Segugio::Advancer_Concrete . . . . .	24
Segugio::BFGS . . . . .	25
Segugio::Fixed_step . . . . .	32
Segugio::Trainer_Decorator . . . . .	68
Segugio::info_neighbourhood::info_neigh . . . . .	46
Segugio::info_neighbourhood . . . . .	46
Segugio::Node::Neighbour_connection . . . . .	50
Segugio::Node . . . . .	50
Segugio::Node::Node_factory . . . . .	51
Segugio::Graph . . . . .	33
Segugio::Graph_Learnable . . . . .	36
Segugio::Conditional_Random_Field . . . . .	29
Segugio::Random_Field . . . . .	64
Segugio::Training_set::subset . . . . .	67
Segugio::Training_set . . . . .	68
Segugio::Graph_Learnable::Weights_Manager . . . . .	71



## Chapter 4

# Class Index

### 4.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Segugio::Node::Node_factory::_Baseline_4_Insertion< T > . . . . .	21
Segugio::Node::Node_factory::_Pot_wrapper_4_Insertion . . . . .	21
Segugio::Node::Node_factory::_SubGraph . . . . .	22
Segugio::Advancer_Concrete . . . . .	24
Segugio::Training_set::Basic_Extractor< Array > Basic extractor, see Training_set(const std::list<std::string>& variable_names, std::list<Array> samples, I_Extractor<Array>* extractor) . . . . .	25
Segugio::BFGS . . . . .	25
Segugio::Binary_handler . . . . .	26
Segugio::Binary_handler_with_Observation . . . . .	26
Segugio::Categoric_domain . . . . .	27
Segugio::Categoric_var Describes a categoric variable . . . . .	27
Segugio::Conditional_Random_Field This class describes Conditional Random fields . . . . .	29
Segugio::Distribution_exp_value . . . . .	30
Segugio::Distribution_value . . . . .	31
Segugio::Entire_Set . . . . .	32
Segugio::Fixed_step . . . . .	32
Segugio::I_Potential::Getter_4_Decorator . . . . .	33
Segugio::Potential_Exp_Shape::Getter_weight_and_shape . . . . .	33
Segugio::Graph Interface for managing generic graphs . . . . .	33
Segugio::Graph_Learnable Interface for managing learnable graphs, i.e. graphs for which it is possible perform learning . . . . .	36
Segugio::Training_set::subset::Handler . . . . .	37
Segugio::I_belief_propagation_strategy . . . . .	38
Segugio::I_Potential::I_Distribution_value Abstract interface for describing a value in the domain of a potential . . . . .	38
Segugio::Training_set::I_Extractor< Array > This class is adopted for parsing a set of samples to import as a novel training set. You have to derive your custom extractor, implementing the two virtual method . . . . .	39
Segugio::I_Learning_handler . . . . .	40
Segugio::I_Potential Abstract interface for potentials handled by graphs . . . . .	40

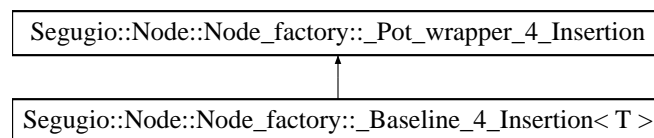
<a href="#">Segugio::I_Potential_Decorator&lt; Wrapped_Type &gt;</a>	
Abstract decorator of a <a href="#">Potential</a> , wrapping an Abstract potential	43
<a href="#">Segugio::I_Trainer</a>	
This class is used by a <a href="#">Graph_Learnable</a> , to perform training with an instance of a <a href="#">Training_set</a>	44
<a href="#">Segugio::info_neighbourhood::info_neigh</a>	46
<a href="#">Segugio::info_neighbourhood</a>	46
<a href="#">Segugio::Loopy_belief_propagation</a>	46
<a href="#">Segugio::Message_Unary</a>	
This class is adopted by belief propagation algorithms. It is the message incoming to a node of the graph. Every node of a graph refers to a single Categorical variable. Internally it keeps track of the difference in time of the messages produced, in order to arrest loopy belief propagation	47
<a href="#">Segugio::Message_Passing</a>	49
<a href="#">Segugio::Node::Neighbour_connection</a>	50
<a href="#">Segugio::Node</a>	50
<a href="#">Segugio::Node::Node_factory</a>	
Interface for describing a net: set of nodes representing random variables	51
<a href="#">Segugio::Potential</a>	
This class is mainly adopted for computing operations on potentials	55
<a href="#">Segugio::Potential_Exp_Shape</a>	
Represents an exponential potential, wrapping a normal shape one: every value of the domain are assumed as $\exp(mWeight * val\_in\_shape\_wrapped)$	57
<a href="#">Segugio::Potential_Shape</a>	
It's the only possible concrete potential. It contains the domain and the image of the potential	60
<a href="#">Segugio::Random_Field</a>	
This class describes a generic Random Field, not having a particular set of variables observed	64
<a href="#">Segugio::Stoch_Set_variation</a>	66
<a href="#">Segugio::Training_set::subset</a>	
This class is describes a portion of a training set, obtained by sampling values in the original set. Mainly used by stochastic gradient computation strategies	67
<a href="#">Segugio::Trainer_Decorator</a>	68
<a href="#">Segugio::Training_set</a>	
This class is used for describing a training set for a graph	68
<a href="#">Segugio::Unary_handler</a>	70
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## Chapter 5

# Class Documentation

### 5.1 Segugio::Node::Node\_factory::\_Baseline\_4\_Insertion< T > Struct Template Reference

Inheritance diagram for Segugio::Node::Node\_factory::\_Baseline\_4\_Insertion< T >:



#### Public Member Functions

- **\_Baseline\_4\_Insertion** (T \*wrp)
- virtual const std::list< [Categoric\\_var](#) \* > \* **Get\_involved\_var\_safe** ()
- virtual [Potential](#) \* **Get\_Potential\_to\_Insert** (const std::list< [Categoric\\_var](#) \* > &var\_involved, const bool &get\_cloned)

#### Protected Attributes

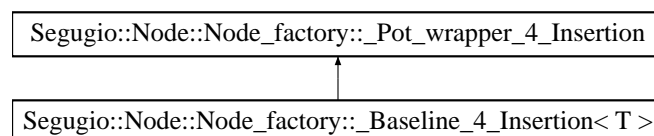
- T \* **wrapped**

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h

### 5.2 Segugio::Node::Node\_factory::\_Pot\_wrapper\_4\_Insertion Struct Reference

Inheritance diagram for Segugio::Node::Node\_factory::\_Pot\_wrapper\_4\_Insertion:



## Public Member Functions

- virtual const std::list< [Categoric\\_var](#) \* > \* **Get\_involved\_var\_safe** ()=0
- virtual [Potential](#) \* **Get\_Potential\_to\_Insert** (const std::list< [Categoric\\_var](#) \* > &var\_involved, const bool &get\_cloned)=0

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h

## 5.3 Segugio::Node::Node\_factory::\_SubGraph Class Reference

### Public Member Functions

- [\\_SubGraph](#) ([Node\\_factory](#) \*Original\_graph, const std::list< [Categoric\\_var](#) \* > &sub\_set\_to\_consider)  
*Builds a reduction of the actual net, considering the actual observation values.*
- void [Get\\_marginal\\_prob\\_combinations](#) (std::list< float > \*result, const std::list< std::list< size\_t >> &combinations, const std::list< [Categoric\\_var](#) \* > &var\_order\_in\_combination)  
*Returns the marginal probability of a some particular combinations of values assumed by the variables in this sub-graph.*
- void [Get\\_marginal\\_prob\\_combinations](#) (std::list< float > \*result, const std::list< size\_t \* > &combinations, const std::list< [Categoric\\_var](#) \* > &var\_order\_in\_combination)  
*Similar to [Get\\_marginal\\_prob\\_combinations](#)(std::list<float>\* result, const std::list< std::list<size\_t>>& combinations, const std::list<Categoric\_var\*>& var\_order\_in\_combination) passing the combinations as pointer arrays.*
- void [MAP](#) (std::list< size\_t > \*result)  
*Returns the Maximum a Posteriori estimation of the hidden set in the sugraph. .*
- void [Gibbs\\_Sampling](#) (std::list< std::list< size\_t >> \*result, const unsigned int &N\_samples, const unsigned int &initial\_sample\_to\_skip)  
*Returns a set of samples for the variables involved in this subgraph. .*
- void [Get\\_All\\_variables](#) (std::list< [Categoric\\_var](#) \* > \*result)  
*Returns the cluster of variables involved in this sub graph.*

### 5.3.1 Constructor & Destructor Documentation

#### 5.3.1.1 \_SubGraph()

```
Segugio::Node::Node_factory::_SubGraph::_SubGraph (
    Node\_factory * Original_graph,
    const std::list< Categoric\_var * > & sub_set_to_consider )
```

Builds a reduction of the actual net, considering the actual observation values.

The subgraph is not automatically updated w.r.t. modifications of the originating net: in such cases just create a novel subgraph with the same sub\_set of variables involved

### 5.3.2 Member Function Documentation

#### 5.3.2.1 Get\_marginal\_prob\_combinations()

```
void Segugio::Node::Node_factory::_SubGraph::Get_marginal_prob_combinations (
    std::list< float > * result,
    const std::list< std::list< size_t >> & combinations,
    const std::list< Categorical_var * > & var_order_in_combination )
```

Returns the marginal probability of a some particular combinations of values assumed by the variables in this sub-graph.

The marginal probabilities computed are conditioned to the observations set when extracting this subgraph.

##### Parameters

out	<i>result</i>	the computed marginal probabilities
in	<i>combinations</i>	combinations of values for which the marginals are computed: must have same size of <i>var_order_in_combination</i> .
in	<i>var_order_in_combination</i>	order of variables considered when assembling the combinations.

#### 5.3.2.2 Gibbs\_Sampling()

```
void Segugio::Node::Node_factory::_SubGraph::Gibbs_Sampling (
    std::list< std::list< size_t >> * result,
    const unsigned int & N_samples,
    const unsigned int & initial_sample_to_skip ) [inline]
```

Returns a set of samples for the variables involved in this subgraph. .

Sampling is done considering the marginal probability distribution of this cluster of variables, conditioned to the observations set at the time this subgraph was created. Samples are obtained through Gibbs sampling. Calculations are done considering the last last observations set (see [Node\\_factory::Set\\_Observation\\_Set\\_var](#))

##### Parameters

in	<i>N_samples</i>	number of desired samples
in	<i>initial_sample_to_skip</i>	number of samples to skip for performing Gibbs sampling
out	<i>result</i>	returned samples: every element of the list is a combination of values for the hidden set, with the same order returned when calling <a href="#">_SubGraph::Get_All_variables</a>

### 5.3.2.3 MAP()

```
void Segugio::Node::Node_factory::_SubGraph::MAP (
    std::list< size_t > * result ) [inline]
```

Returns the Maximum a Posteriori estimation of the hidden set in the sugraph. .

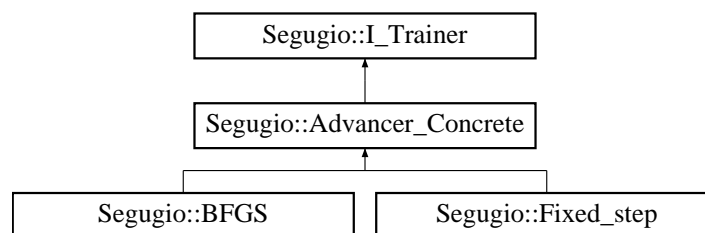
Values are ordered as returned by [\\_SubGraph::Get\\_All\\_variables](#). This MAP is conditioned to the observations set at the time this subgraph was created.

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Subgraph.cpp

## 5.4 Segugio::Advancer\_Concrete Class Reference

Inheritance diagram for Segugio::Advancer\_Concrete:



### Public Member Functions

- virtual void **Reset** ()
- void **Train** ([Graph\\_Learnable](#) \*model\_to\_train, [Training\\_set](#) \*Train\_set, const unsigned int &Max\_Iterations, std::list< float > \*descend\_story)
- virtual float **\_advance** ([Graph\\_Learnable](#) \*model\_to\_advance, const std::list< size\_t \* > &comb\_in\_train↔\_set, const std::list< [Categoric\\_var](#) \* > &comb\_var)=0

### Additional Inherited Members

The documentation for this class was generated from the following file:

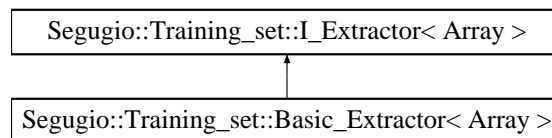
- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.5 Segugio::Training\_set::Basic\_Extractor< Array > Class Template Reference

Basic extractor, see Training\_set(const std::list<std::string>& variable\_names, std::list<Array> samples, I\_Extractor<Array>\* extractor)

```
#include <Training_set.h>
```

Inheritance diagram for Segugio::Training\_set::Basic\_Extractor< Array >:



### Additional Inherited Members

#### 5.5.1 Detailed Description

```
template<typename Array>
class Segugio::Training_set::Basic_Extractor< Array >
```

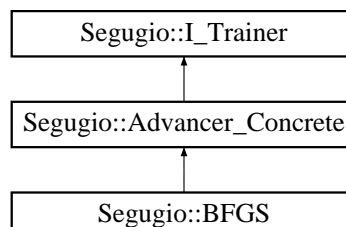
Basic extractor, see Training\_set(const std::list<std::string>& variable\_names, std::list<Array> samples, I\_Extractor<Array>\* extractor)

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Header/Training\_set.h

## 5.6 Segugio::BFGS Class Reference

Inheritance diagram for Segugio::BFGS:



### Public Member Functions

- void **Reset** ()

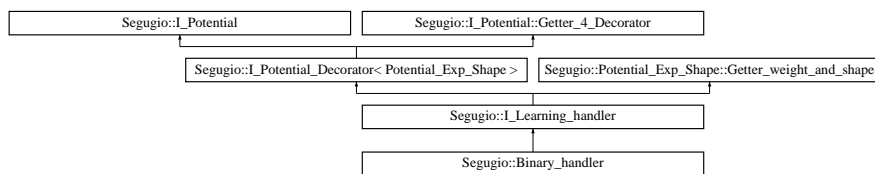
## Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.7 Segugio::Binary\_handler Class Reference

Inheritance diagram for Segugio::Binary\_handler:



## Public Member Functions

- **Binary\_handler** ([Node](#) \*N1, [Node](#) \*N2, [Potential\\_Exp\\_Shape](#) \*pot\_to\_handle)

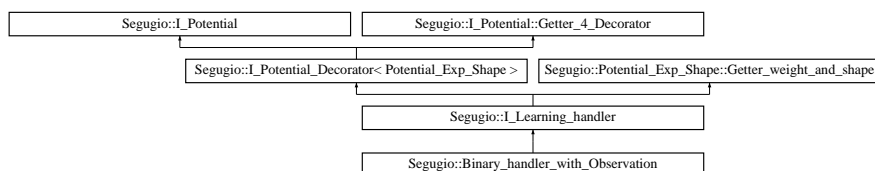
## Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.8 Segugio::Binary\_handler\_with\_Observation Class Reference

Inheritance diagram for Segugio::Binary\_handler\_with\_Observation:



## Public Member Functions

- **Binary\_handler\_with\_Observation** ([Node](#) \*Hidden\_var, size\_t \*observed\_val, [I\\_Learning\\_handler](#) \*handle\_to\_substitute)



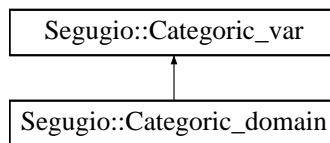
### Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.9 Segugio::Categoric\_domain Class Reference

Inheritance diagram for Segugio::Categoric\_domain:



### Public Member Functions

- const float & **operator[]** (const size\_t &pos)

### Additional Inherited Members

The documentation for this class was generated from the following files:

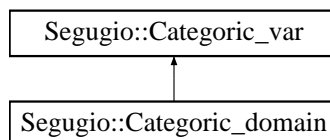
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.10 Segugio::Categoric\_var Class Reference

Describes a categoric variable.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::Categoric\_var:



### Public Member Functions

- [Categoric\\_var](#) (const size\_t &size, const std::string &name)  
*domain is assumed to be {0,1,2,3,...,size}*
- **Categoric\_var** (const [Categoric\\_var](#) &to\_copy)
- const size\_t & **size** () const
- const std::string & **Get\_name** ()

## Protected Attributes

- `size_t` **Size**
- `std::string` [Name](#)

### 5.10.1 Detailed Description

Describes a categoric variable.

, having a finite set as domain, assumed by default as {0,1,2,3,...,size}

### 5.10.2 Constructor & Destructor Documentation

#### 5.10.2.1 `Categoric_var()`

```
Segugio::Categoric_var::Categoric_var (
    const size_t & size,
    const std::string & name )
```

domain is assumed to be {0,1,2,3,...,size}

#### Parameters

in	<i>size</i>	domain size of this variable
in	<i>name</i>	name to attach to this variable. It cannot be an empty string ""

### 5.10.3 Member Data Documentation

#### 5.10.3.1 `Name`

```
std::string Segugio::Categoric_var::Name [protected]
```

domain size

The documentation for this class was generated from the following files:

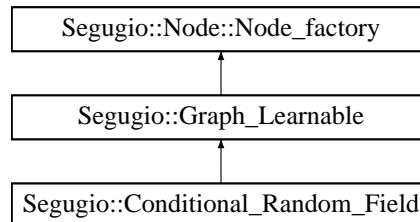
- `C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h`
- `C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp`

## 5.11 Segugio::Conditional\_Random\_Field Class Reference

This class describes Conditional Random fields.

```
#include <Graphical_model.h>
```

Inheritance diagram for Segugio::Conditional\_Random\_Field:



### Public Member Functions

- [Conditional\\_Random\\_Field](#) (const std::string &config\_xml\_file, const std::string &prefix\_config\_xml\_file="")  
*The model is built considering the information contained in an xml configuration file. .*
- [Conditional\\_Random\\_Field](#) (const std::list< [Potential\\_Exp\\_Shape](#) \* > &potentials, const std::list< [Categoric\\_var](#) \* > &observed\_var, const bool &use\_cloning\_Insert=true, const std::list< bool > &tunable←\_mask={}, const std::list< [Potential\\_Shape](#) \* > &shapes={})  
*This constructor initializes the graph with the specified potentials passed as input, setting the variables passed as the one observed.*
- void [Set\\_Observation\\_Set\\_val](#) (const std::list< size\_t > &new\_observed\_vals)  
*see [Node::Node\\_factory::Set\\_Observation\\_Set\\_val\(const std::list<size\\_t> & new\\_observed\\_vals\)](#)*

### Additional Inherited Members

#### 5.11.1 Detailed Description

This class describes Conditional Random fields.

Set\_Observation\_Set\_var is depracated: the observed set of variables cannot be changed after construction.

#### 5.11.2 Constructor & Destructor Documentation

##### 5.11.2.1 Conditional\_Random\_Field() [1/2]

```
Segugio::Conditional_Random_Field::Conditional_Random_Field (
    const std::string & config_xml_file,
    const std::string & prefix_config_xml_file = "" )
```

The model is built considering the information contained in an xml configuration file. .

See Section 2 of the documentation for the syntax to adopt.

## Parameters

in	<i>configuration</i>	file
in	<i>prefix</i>	to use. The file prefix_config_xml_file/config_xml_file is searched.

## 5.11.2.2 Conditional\_Random\_Field() [2/2]

```
Segugio::Conditional_Random_Field::Conditional_Random_Field (
    const std::list< Potential_Exp_Shape * > & potentials,
    const std::list< Categorical_var * > & observed_var,
    const bool & use_cloning_Insert = true,
    const std::list< bool > & tunable_mask = {},
    const std::list< Potential_Shape * > & shapes = {} )
```

This constructor initializes the graph with the specified potentials passed as input, setting the variables passed as the one observed.

## Parameters

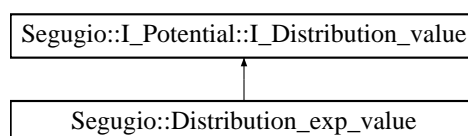
in	<i>potentials</i>	the initial set of exponential potentials to insert (can be empty)
in	<i>observed_var</i>	the set of variables to assume as observations
in	<i>use_cloning_Insert</i>	when is true, every time an Insert of a novel potential is called (this includes the passed potentials), a copy of that potential is actually inserted. Otherwise, the passed potential is inserted as is: this can be dangerous, cause that potential can be externally modified, but the construction of a novel graph is faster.
in	<i>tunable_mask</i>	when passed as non default value, it must have the same size of potentials. Every value in this list is true if the corresponding potential in the potentials list is tunable, i.e. has a weight whose value can vary with learning
in	<i>shapes</i>	A list of additional non learnable potentials to insert in the model

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Graphical\_model.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.12 Segugio::Distribution\_exp\_value Struct Reference

Inheritance diagram for Segugio::Distribution\_exp\_value:



### Public Member Functions

- **Distribution\_exp\_value** ([Distribution\\_value](#) \*to\_wrap, float \*weight)
- void **Set\_val** (const float &v)
- void **Get\_val** (float \*result)
- size\_t \* **Get\_indices** ()

### Protected Attributes

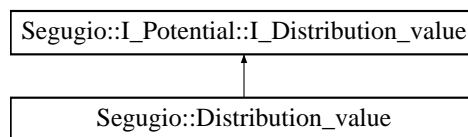
- float \* **w**
- [Distribution\\_value](#) \* **wrapped**

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.13 Segugio::Distribution\_value Struct Reference

Inheritance diagram for Segugio::Distribution\_value:



### Public Member Functions

- **Distribution\_value** (size\_t \*ind, const float &v=0.f)
- void **Set\_val** (const float &v)
- void **Get\_val** (float \*result)
- size\_t \* **Get\_indices** ()

### Protected Attributes

- size\_t \* **indices**
- float **val**

### Friends

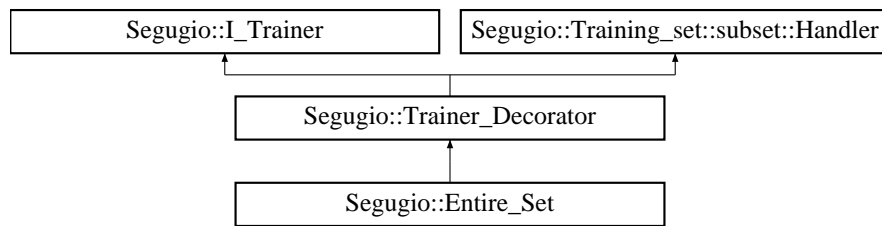
- struct **Distribution\_exp\_value**

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.14 Segugio::Entire\_Set Class Reference

Inheritance diagram for Segugio::Entire\_Set:



### Public Member Functions

- **Entire\_Set** ([Advancer\\_Concrete](#) \*to\_wrap)
- void **Train** ([Graph\\_Learnable](#) \*model\_to\_train, [Training\\_set](#) \*Train\_set, const unsigned int &Max\_Iterations, std::list< float > \*descend\_story)

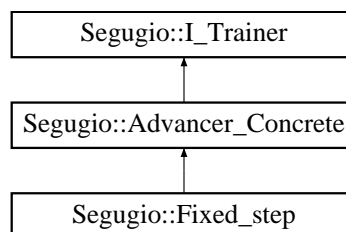
### Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.15 Segugio::Fixed\_step Class Reference

Inheritance diagram for Segugio::Fixed\_step:



### Public Member Functions

- **Fixed\_step** (const float &step)

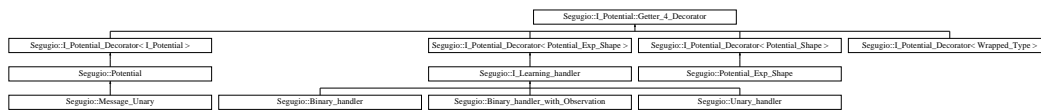
### Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.16 Segugio::I\_Potential::Getter\_4\_Decorator Struct Reference

Inheritance diagram for Segugio::I\_Potential::Getter\_4\_Decorator:



### Static Protected Member Functions

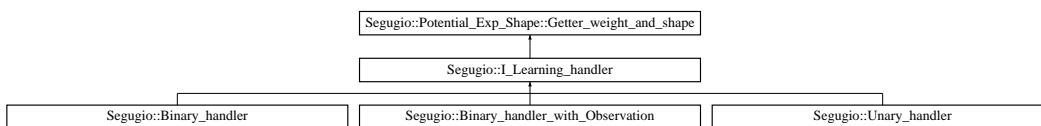
- static const std::list< [Categoric\\_var](#) \* > \* [Get\\_involved\\_var](#) ([I\\_Potential](#) \*pot)
- static std::list< [I\\_Distribution\\_value](#) \* > \* [Get\\_distr](#) ([I\\_Potential](#) \*pot)

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h

## 5.17 Segugio::Potential\_Exp\_Shape::Getter\_weight\_and\_shape Struct Reference

Inheritance diagram for Segugio::Potential\_Exp\_Shape::Getter\_weight\_and\_shape:



### Static Protected Member Functions

- static float \* [Get\\_weight](#) ([Potential\\_Exp\\_Shape](#) \*pot)
- static [Potential\\_Shape](#) \* [Get\\_shape](#) ([Potential\\_Exp\\_Shape](#) \*pot)

The documentation for this struct was generated from the following file:

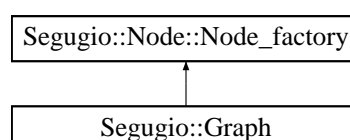
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h

## 5.18 Segugio::Graph Class Reference

Interface for managing generic graphs.

```
#include <Graphical_model.h>
```

Inheritance diagram for Segugio::Graph:



## Public Member Functions

- [Graph](#) (const bool &use\_cloning\_Insert=true)  
*empty constructor*
- [Graph](#) (const std::string &config\_xml\_file, const std::string &prefix\_config\_xml\_file="")  
*The model is built considering the information contained in an xml configuration file. .*
- [Graph](#) (const std::list< [Potential\\_Shape](#) \* > &potentials, const std::list< [Potential\\_Exp\\_Shape](#) \* > &potentials\_exp, const bool &use\_cloning\_Insert=true)  
*This constructor initializes the graph with the specified potentials passed as input.*
- void [Insert](#) ([Potential\\_Shape](#) \*pot)  
*The model is built considering the information contained in an xml configuration file.*
- void [Insert](#) ([Potential\\_Exp\\_Shape](#) \*pot)  
*The model is built considering the information contained in an xml configuration file.*
- void [Set\\_Observation\\_Set\\_var](#) (const std::list< [Categoric\\_var](#) \* > &new\_observed\_vars)  
*see [Node::Node\\_factory::Set\\_Observation\\_Set\\_var\(const std::list<Categoric\\_var\\*> & new\\_observed\\_vars\)](#)*
- void [Set\\_Observation\\_Set\\_val](#) (const std::list< size\_t > &new\_observed\_vals)  
*see [Node::Node\\_factory::Set\\_Observation\\_Set\\_val\(const std::list<size\\_t> & new\\_observed\\_vals\)](#)*

## Additional Inherited Members

### 5.18.1 Detailed Description

Interface for managing generic graphs.

Both Exponential and normal shapes can be included into the model. Learning is not possible: all belief propagation operations are performed assuming the mdoel as is. Every [Potential\\_Shape](#) or [Potential\\_Exp\\_Shape](#) is copied and that copy is inserted into the model.

### 5.18.2 Constructor & Destructor Documentation

#### 5.18.2.1 [Graph\(\)](#) [1/3]

```
Segugio::Graph::Graph (
    const bool & use_cloning_Insert = true ) [inline]
```

empty constructor

#### Parameters

in	<a href="#">use_cloning_Insert</a>	when is true, every time an Insert of a novel potential is called, a copy of that potential is actually inserted. Otherwise, the passed potential is inserted as is: this can be dangerous, cause that potential cna be externally modified, but the construction of a novel graph is faster.
----	------------------------------------	---



## 5.18.2.2 Graph() [2/3]

```
Segugio::Graph::Graph (
    const std::string & config_xml_file,
    const std::string & prefix_config_xml_file = "" )
```

The model is built considering the information contained in an xml configuration file. .

See Section 2 of the documentation for the syntax to adopt.

## Parameters

in	<i>configuration</i>	file
in	<i>prefix</i>	to use. The file prefix_config_xml_file/config_xml_file is searched.

## 5.18.2.3 Graph() [3/3]

```
Segugio::Graph::Graph (
    const std::list< Potential_Shape * > & potentials,
    const std::list< Potential_Exp_Shape * > & potentials_exp,
    const bool & use_cloning_Insert = true )
```

This constructor initializes the graph with the specified potentials passed as input.

## Parameters

in	<i>potentials</i>	the initial set of potentials to insert (can be empty)
in	<i>potentials_exp</i>	the initial set of exponential potentials to insert (can be empty)
in	<i>use_cloning_Insert</i>	when is true, every time an Insert of a novel potential is called (this includes the passed potentials), a copy of that potential is actually inserted. Otherwise, the passed potential is inserted as is: this can be dangerous, cause that potential can be externally modified, but the construction of a novel graph is faster.

## 5.18.3 Member Function Documentation

## 5.18.3.1 Insert() [1/2]

```
void Segugio::Graph::Insert (
    Potential_Shape * pot ) [inline]
```

The model is built considering the information contained in an xml configuration file.

## Parameters

in	<i>the</i>	potential to insert. It can be a unary or a binary potential. In case it is binary, at least one of the variable involved must be already inserted to the model before (with a previous Insert having as input a potential which involves that variable).
----	------------	---

## 5.18.3.2 Insert() [2/2]

```
void Segugio::Graph::Insert (
    Potential_Exp_Shape * pot ) [inline]
```

The model is built considering the information contained in an xml configuration file.

## Parameters

in	<i>the</i>	potential to insert. It can be a unary or a binary potential. In case it is binary, at least one of the variable involved must be already inserted to the model before (with a previous Insert having as input a potential which involves that variable).
----	------------	---

The documentation for this class was generated from the following files:

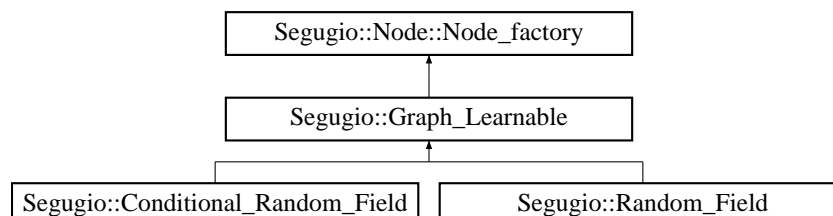
- C:/Users/andre/Desktop/CRF/CRF/Header/Graphical\_model.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.19 Segugio::Graph\_Learnable Class Reference

Interface for managing learnable graphs, i.e. graphs for which it is possible perform learning.

```
#include <Graphical_model.h>
```

Inheritance diagram for Segugio::Graph\_Learnable:



## Classes

- struct [Weights\\_Manager](#)

## Public Member Functions

- `size_t Get_model_size ()`  
*Returns the model size, i.e. the number of tunable parameters of the model, i.e. the number of weigths that can vary with learning.*
- `void Get_Likelihood_estimation (float *result, const std::list< size_t * > &comb_train_set, const std::list< Categorical_var * > &comb_var_order)`
- `void Get_structure (std::list< const Potential_Exp_Shape * > *result)`  
*Returns the list of potentials constituting the net. Usefull for structural learning.*

## Protected Member Functions

- `virtual _Pot_wrapper_4_Insertion * Get_Inserter (Potential_Exp_Shape *pot, const bool &weight_tunability)`
- `Graph_Learnable (const bool &use_cloning_Insert)`
- `Graph_Learnable (const std::list< Potential_Exp_Shape * > &potentials_exp, const bool &use_cloning_Insert, const std::list< bool > &tunable_mask, const std::list< Potential_Shape * > &shapes)`

## Protected Attributes

- `std::list< I_Learning_handler * > Model_handlers`

### 5.19.1 Detailed Description

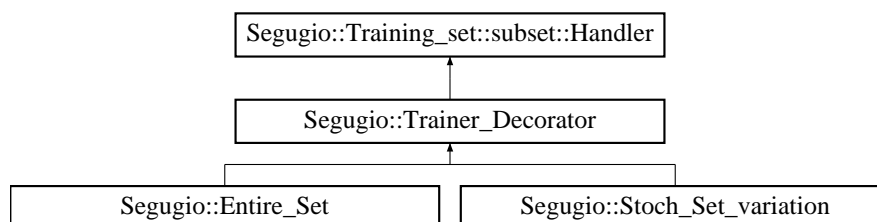
Interface for managing learnable graphs, i.e. graphs for which it is possible perform learning.

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Graphical\_model.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.20 Segugio::Training\_set::subset::Handler Struct Reference

Inheritance diagram for Segugio::Training\_set::subset::Handler:



## Static Protected Member Functions

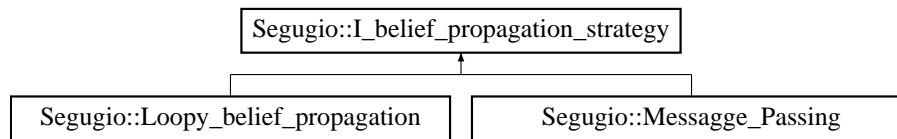
- `static std::list< size_t * > * Get_list (subset *sub_set)`
- `static std::list< std::string > * Get_names (subset *sub_set)`
- `static std::list< std::string > * Get_names (Training_set *set)`

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Header/Training\_set.h

## 5.21 Segugio::I\_belief\_propagation\_strategy Class Reference

Inheritance diagram for Segugio::I\_belief\_propagation\_strategy:



### Static Public Member Functions

- static bool **Propagate** (std::list< [Node](#) \* > &cluster, const bool &sum\_or\_MAP=true, const unsigned int &Iterations=1000)

### Protected Member Functions

- void **Instantiate\_message** ([Node::Neighbour\\_connection](#) \*outgoing\_mex\_to\_compute, const bool &sum\_or\_MAP)
- void **Update\_message** (float \*variation\_to\_previous, [Node::Neighbour\\_connection](#) \*outgoing\_mex\_to\_compute, const bool &sum\_or\_MAP)
- void **Gather\_incoming\_messages** (std::list< [Potential](#) \* > \*result, [Node::Neighbour\\_connection](#) \*outgoing\_mex\_to\_compute)
- std::list< [Node::Neighbour\\_connection](#) \* > \* **Get\_Neighbourhood** ([Node::Neighbour\\_connection](#) \*conn)
- [Message\\_Unary](#) \*\* **Get\_Mex\_to\_This** ([Node::Neighbour\\_connection](#) \*conn)
- [Message\\_Unary](#) \*\* **Get\_Mex\_to\_Neigh** ([Node::Neighbour\\_connection](#) \*conn)

The documentation for this class was generated from the following files:

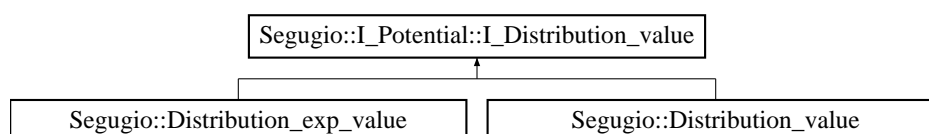
- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Belief\_propagation.cpp

## 5.22 Segugio::I\_Potential::I\_Distribution\_value Struct Reference

Abstract interface for describing a value in the domain of a potential.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::I\_Potential::I\_Distribution\_value:



## Public Member Functions

- virtual void **Set\_val** (const float &v)=0
- virtual void **Get\_val** (float \*result)=0
- virtual size\_t \* **Get\_indeces** ()=0

### 5.22.1 Detailed Description

Abstract interface for describing a value in the domain of a potential.

The documentation for this struct was generated from the following file:

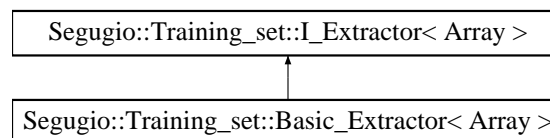
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h

## 5.23 Segugio::Training\_set::I\_Extractor< Array > Class Template Reference

This class is adopted for parsing a set of samples to import as a novel training set. You have to derive your custom extractor, implementing the two virtual methods.

```
#include <Training_set.h>
```

Inheritance diagram for Segugio::Training\_set::I\_Extractor< Array >:



## Public Member Functions

- virtual const size\_t & **get\_val\_in\_pos** (const Array &container, const size\_t &pos)=0
- virtual size\_t **get\_size** (const Array &container)=0

### 5.23.1 Detailed Description

```
template<typename Array>
class Segugio::Training_set::I_Extractor< Array >
```

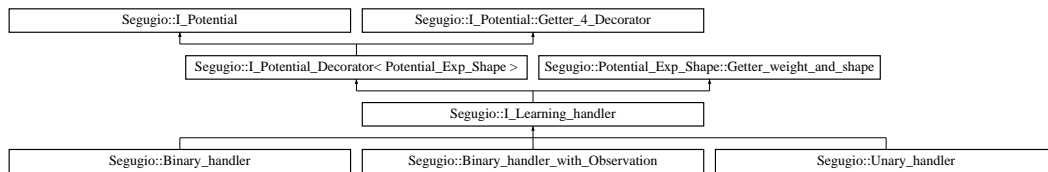
This class is adopted for parsing a set of samples to import as a novel training set. You have to derive your custom extractor, implementing the two virtual methods.

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Header/Training\_set.h

## 5.24 Segugio::I\_Learning\_handler Class Reference

Inheritance diagram for Segugio::I\_Learning\_handler:



### Public Member Functions

- void **Get\_weight** (float \*w)
- void **Set\_weight** (const float &w\_new)
- void **Get\_grad\_alfa\_part** (float \*alfa, const std::list< size\_t \* > &comb\_in\_train\_set, const std::list< [Categoric\\_var](#) \* > &comb\_var)
- virtual void **Get\_grad\_beta\_part** (float \*beta)=0
- const [Potential\\_Exp\\_Shape](#) \* **get\_wrapped\_exp\_pot** ()

### Protected Member Functions

- **I\_Learning\_handler** ([Potential\\_Exp\\_Shape](#) \*pot\_to\_handle)
- **I\_Learning\_handler** ([I\\_Learning\\_handler](#) \*other)

### Protected Attributes

- float \* **pWeight**
- std::list< I\_Distribution\_value \* > **Extended\_shape\_domain**

### Additional Inherited Members

The documentation for this class was generated from the following files:

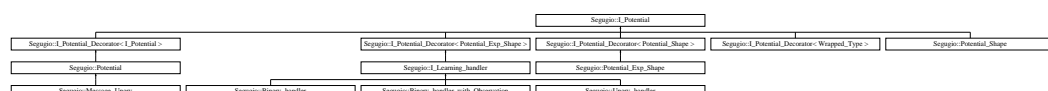
- C:/Users/andre/Desktop/CRF/CRF/Header/Graphical\_model.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.25 Segugio::I\_Potential Class Reference

Abstract interface for potentials handled by graphs.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::I\_Potential:



## Classes

- struct [Getter\\_4\\_Decorator](#)
- struct [I\\_Distribution\\_value](#)

*Abstract interface for describing a value in the domain of a potential.*

## Public Member Functions

- **I\_Potential** (const [I\\_Potential](#) &to\_copy)
- void [Print\\_distribution](#) (std::ostream &f, const bool &print\_entire\_domain=false)  
*when print\_entire\_domain is true, the entire domain is printed, even though the potential has a sparse distribution*
- const std::list< [Categoric\\_var](#) \* > \* [Get\\_involved\\_var\\_safe](#) () const  
*return list of references to the variables representing the domain of this Potential*
- void [Find\\_Comb\\_in\\_distribution](#) (std::list< float > \*result, const std::list< size\_t \* > &comb\_to\_search, const std::list< [Categoric\\_var](#) \* > &comb\_to\_search\_var\_order)
- float [max\\_in\\_distribution](#) ()  
*Returns the maximum value in the distribution describing this potential.*

## Static Public Member Functions

- static void [Get\\_entire\\_domain](#) (std::list< std::list< size\_t >> \*domain, const std::list< [Categoric\\_var](#) \* > &Vars\_in\_domain)  
*get entire domain of a group of variables: list of possible combinations*
- static void [Get\\_entire\\_domain](#) (std::list< size\_t \* > \*domain, const std::list< [Categoric\\_var](#) \* > &Vars\_in\_domain)  
*Same as [Get\\_entire\\_domain](#)(std::list<std::list<size\_t>>\* domain, const std::list<Categoric\_var\*>& Vars\_in\_domain), but adopting array internally allocated with malloc instead of list: remembre to delete combinations.*

## Protected Member Functions

- virtual const std::list< [Categoric\\_var](#) \* > \* [Get\\_involved\\_var](#) () const =0
- virtual std::list< [I\\_Distribution\\_value](#) \* > \* [Get\\_distr](#) ()=0

## Static Protected Member Functions

- static void [Find\\_Comb\\_in\\_distribution](#) (std::list< [I\\_Distribution\\_value](#) \* > \*result, const std::list< size\_t \* > &comb\_to\_search, const std::list< [Categoric\\_var](#) \* > &comb\_to\_search\_var\_order, [I\\_Potential](#) \*pot)
- static void [Find\\_Comb\\_in\\_distribution](#) (std::list< [I\\_Distribution\\_value](#) \* > \*result, size\_t \*partial\_comb\_to\_search, const std::list< [Categoric\\_var](#) \* > &partial\_comb\_to\_search\_var\_order, [I\\_Potential](#) \*pot)

### 5.25.1 Detailed Description

Abstract interface for potentials handled by graphs.

### 5.25.2 Member Function Documentation

#### 5.25.2.1 Find\_Comb\_in\_distribution()

```
void Segugio::I_Potential::Find_Comb_in_distribution (
    std::list< float > * result,
    const std::list< size_t * > & comb_to_search,
    const std::list< Categoric\_var * > & comb_to_search_var_order )
```

## Parameters

out	<i>result</i>	the list of values matching the combinations to find sent as input
in	<i>comb_to_search</i>	domain list of combinations (i.e. values of the domain) whose values are to find
in	<i>comb_to_search_var_order</i>	order of variables used for assembling the combinations to find

5.25.2.2 `Get_entire_domain()` [1/2]

```
void Segugio::I_Potential::Get_entire_domain (
    std::list< std::list< size_t >> * domain,
    const std::list< Categorical_var * > & Vars_in_domain ) [static]
```

get entire domain of a group of variables: list of possible combinations

## Parameters

out	<i>domain</i>	the entire set of possible combinations
in	<i>Vars_in_domain</i>	variables involved whose domain has to be compute

5.25.2.3 `Get_entire_domain()` [2/2]

```
static void Segugio::I_Potential::Get_entire_domain (
    std::list< size_t * > * domain,
    const std::list< Categorical_var * > & Vars_in_domain ) [static]
```

Same as `Get_entire_domain(std::list<std::list<size_t>>* domain, const std::list<Categorical_var*>& Vars_in_domain)`, but adopting array internally allocated with malloc instead of list: remembre to delete combinations.

## Parameters

out	<i>domain</i>	the entire set of possible combinations
in	<i>Vars_in_domain</i>	variables involved whose domain has to be compute

5.25.2.4 `Print_distribution()`

```
void Segugio::I_Potential::Print_distribution (
    std::ostream & f,
    const bool & print_entire_domain = false )
```

when `print_entire_domain` is true, the entire domain is printed, even though the potential has a sparse distribution



## Parameters

in	<i>f</i>	out stream to target
in	<i>print_entire_domain</i>	

The documentation for this class was generated from the following files:

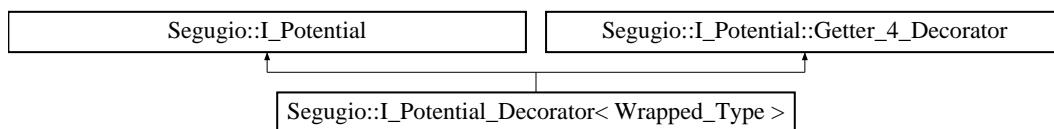
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.26 Segugio::I\_Potential\_Decorator< Wrapped\_Type > Class Template Reference

Abstract decorator of a [Potential](#), wrapping an Abstract potential.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::I\_Potential\_Decorator< Wrapped\_Type >:



### Protected Member Functions

- **I\_Potential\_Decorator** (Wrapped\_Type \*to\_wrap)
- virtual const std::list< [Categoric\\_var](#) \* > \* **Get\_involved\_var** () const
- virtual std::list< [I\\_Distribution\\_value](#) \* > \* **Get\_distr** ()

### Protected Attributes

- bool **Destroy\_wrapped**
- Wrapped\_Type \* [pwrapped](#)

### Additional Inherited Members

#### 5.26.1 Detailed Description

```
template<typename Wrapped_Type>
class Segugio::I_Potential_Decorator< Wrapped_Type >
```

Abstract decorator of a [Potential](#), wrapping an Abstract potential.

## 5.26.2 Member Data Documentation

### 5.26.2.1 pwrapped

```
template<typename Wrapped_Type>
Wrapped_Type* Segugio::I_Potential_Decorator< Wrapped_Type >::pwrapped [protected]
```

when false, the wrapped abstract potential is wrapped also in another decorator, whihc is in charge of deleting the wrapped potential

The documentation for this class was generated from the following file:

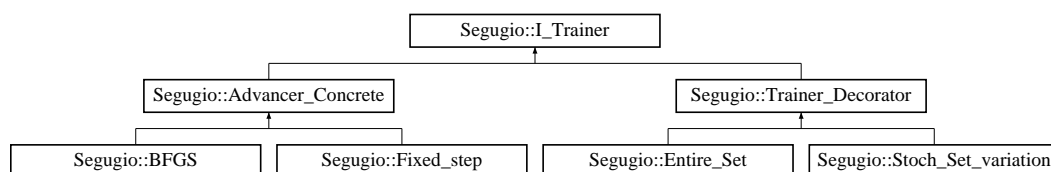
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h

## 5.27 Segugio::I\_Trainer Class Reference

This class is used by a [Graph\\_Learnable](#), to perform training with an instance of a [Training\\_set](#).

```
#include <Trainer.h>
```

Inheritance diagram for Segugio::I\_Trainer:



### Public Member Functions

- virtual void **Train** ([Graph\\_Learnable](#) \*model\_to\_train, [Training\\_set](#) \*Train\_set, const unsigned int &Max\_Iterations=100, std::list< float > \*descend\_story=NULL)=0

### Static Public Member Functions

- static [I\\_Trainer](#) \* **Get\_fixed\_step** (const float &step\_size=0.1f, const float &stoch\_grad\_percentage=1.f)  
*Creates a fixed step gradient descend solver.*
- static [I\\_Trainer](#) \* **Get\_BFGS** (const float &stoch\_grad\_percentage=1.f)  
*Creates a BFGS gradient descend solver ( [https://en.wikipedia.org/wiki/Broyden%E2%80%93Fletcher%E2%80%93Goldfarb%E2%80%93Shanno\\_algorithm](https://en.wikipedia.org/wiki/Broyden%E2%80%93Fletcher%E2%80%93Goldfarb%E2%80%93Shanno_algorithm))*

### Protected Member Functions

- virtual void **Clean\_Up** ()
- void **Get\_w\_grad** ([Graph\\_Learnable](#) \*model, std::list< float > \*grad\_w, const std::list< size\_t \* > &comb\_in\_train\_set, const std::list< [Categoric\\_var](#) \* > &comb\_var)
- void **Set\_w** (const std::list< float > &w, [Graph\\_Learnable](#) \*model)

## Static Protected Member Functions

- static void **Clean\_Up** ([I\\_Trainer](#) \*to\_Clean)

### 5.27.1 Detailed Description

This class is used by a [Graph\\_Learnable](#), to perform training with an instance of a [Training\\_set](#).

Instantiate a particular class of trainer to use by calling `Get_fixed_step` or `Get_BFGS`. That methods allocate in the heap a trainer to use later, for multiple training sessions. Remember to delete the instantiated trainer.

### 5.27.2 Member Function Documentation

#### 5.27.2.1 Get\_BFGS()

```
I\_Trainer * Segugio::I_Trainer::Get_BFGS (
    const float & stoch_grad_percentage = 1.f ) [static]
```

Creates a [BFGS](#) gradient descend solver ( [https://en.wikipedia.org/wiki/Broyden%E2%80%93Fletcher%E2%80%93Goldfarb%E2%80%93Shanno\\_algorithm](https://en.wikipedia.org/wiki/Broyden%E2%80%93Fletcher%E2%80%93Goldfarb%E2%80%93Shanno_algorithm))

##### Parameters

in	<i>stoch_grad_percentage</i>	percentage of the training set to use every time for evaluating the gradient
----	------------------------------	--

#### 5.27.2.2 Get\_fixed\_step()

```
I\_Trainer * Segugio::I_Trainer::Get_fixed_step (
    const float & step_size = 0.1f,
    const float & stoch_grad_percentage = 1.f ) [static]
```

Creates a fixed step gradient descend solver.

##### Parameters

in	<i>step_size</i>	learning degree
in	<i>stoch_grad_percentage</i>	percentage of the training set to use every time for evaluating the gradient

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Trainer.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.28 Segugio::info\_neighbourhood::info\_neigh Struct Reference

### Public Attributes

- [Potential](#) \* **shared\_potential**
- [Categoric\\_var](#) \* **Var**
- size\_t **Var\_pos**

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Node.cpp

## 5.29 Segugio::info\_neighbourhood Struct Reference

### Classes

- struct [info\\_neigh](#)

### Public Attributes

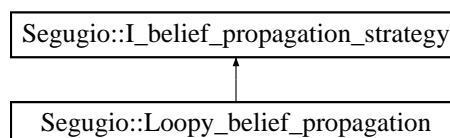
- size\_t **Involved\_var\_pos**
- list< [info\\_neigh](#) > **Info**
- list< [Potential](#) \* > **Unary\_potentials**

The documentation for this struct was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Node.cpp

## 5.30 Segugio::Loopy\_belief\_propagation Class Reference

Inheritance diagram for Segugio::Loopy\_belief\_propagation:



### Public Member Functions

- **Loopy\_belief\_propagation** (const int &max\_iter)
- **bool \_propagate** (std::list< [Node](#) \* > &cluster, const bool &sum\_or\_MAP)

## Protected Attributes

- unsigned int **Iter**

## Additional Inherited Members

The documentation for this class was generated from the following files:

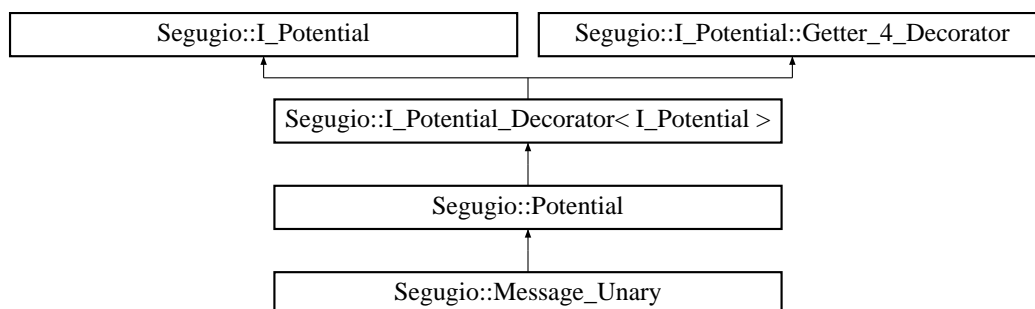
- C:/Users/andre/Desktop/CRF/CRF/Header/Belief\_propagation.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Belief\_propagation.cpp

## 5.31 Segugio::Message\_Unary Class Reference

This class is adopted by belief propagation algorithms. It is the message incoming to a node of the graph. Every node of a graph refers to a single Categorical variable. Internally it keeps track of the difference in time of the messages produced, in order to arrest loopy belief propagation.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::Message\_Unary:



## Public Member Functions

- [Message\\_Unary](#) ([Categoric\\_var](#) \*var\_involved)  
*Creates a Message with all 1 as values for the image.*
- [Message\\_Unary](#) ([Potential](#) \*binary\_to\_merge, const std::list< [Potential](#) \* > &potential\_to\_merge, const bool &Sum\_or\_MAP=true)  
*Firstly, all potential\_to\_merge are merged together using Potential::Potential(potential\_to\_merge, false) obtaining a merged potential. Secondly, the product of binary\_to\_merge and the merged potential is obtained. Finally the message is obtained by marginalizing from the second product, the variable of potential\_to\_merge, adopting a sum or a MAP. Exploited by message passing algorithms.*
- [Message\\_Unary](#) ([Potential](#) \*binary\_to\_merge, [Categoric\\_var](#) \*var\_to\_marginalize, const bool &Sum\_or\_MAP=true)  
*Same as [Message\\_Unary::Message\\_Unary](#)(Potential\* binary\_to\_merge, const std::list<Potential\*> & potential\_to\_merge, const bool & Sum\_or\_MAP = true), but in the case potential\_to\_merge is empty.*
- void [Update](#) (float \*diff\_to\_previous, [Potential](#) \*binary\_to\_merge, const std::list< [Potential](#) \* > &potential\_to\_merge, const bool &Sum\_or\_MAP=true)  
*Adopted by loopy belief propagation.*
- void [Update](#) (float \*diff\_to\_previous, [Potential](#) \*binary\_to\_merge, [Categoric\\_var](#) \*var\_to\_marginalize, const bool &Sum\_or\_MAP=true)  
*Adopted by loopy belief propagation.*

## Additional Inherited Members

### 5.31.1 Detailed Description

This class is adopted by belief propagation algorithms. It is the message incoming to a node of the graph. Every node of a graph refers to a single Categorical variable. Internally it keeps track of the difference in time of the messages produced, in order to arrest loopy belief propagation.

### 5.31.2 Constructor & Destructor Documentation

#### 5.31.2.1 Message\_Unary() [1/2]

```
Segugio::Message_Unary::Message_Unary (
    Categorical_var * var_involved )
```

Creates a Message with all 1 as values for the image.

##### Parameters

in	<i>var_involved</i>	the only variable in the domain
----	---------------------	---------------------------------

#### 5.31.2.2 Message\_Unary() [2/2]

```
Segugio::Message_Unary::Message_Unary (
    Potential * binary_to_merge,
    const std::list< Potential * > & potential_to_merge,
    const bool & Sum_or_MAP = true )
```

Firstly, all *potential\_to\_merge* are merged together using `Potential::Potential(potential_to_merge, false)` obtaining a merged potential. Secondly, the product of *binary\_to\_merge* and the merged potential is obtained. Finally the message is obtained by marginalizing from the second product, the variable of *potential\_to\_merge*, adopting a sum or a MAP. Exploited by message passing algorithms.

##### Parameters

in	<i>binary_to_merge</i>	binaty potential to consider
in	<i>potential_to_merge</i>	list of potentials to merge. The must be unary potentials

### 5.31.3 Member Function Documentation

## 5.31.3.1 Update() [1/2]

```
void Segugio::Message_Unary::Update (
    float * diff_to_previous,
    Potential * binary_to_merge,
    const std::list< Potential * > & potential_to_merge,
    const bool & Sum_or_MAP = true )
```

Adopted by loopy belief propagation.

## Parameters

out	<i>diff_to_previous</i>	The difference with respect to the previous message camptation
-----	-------------------------	--

## 5.31.3.2 Update() [2/2]

```
void Segugio::Message_Unary::Update (
    float * diff_to_previous,
    Potential * binary_to_merge,
    Categorical_var * var_to_marginalize,
    const bool & Sum_or_MAP = true )
```

Adopted by loopy belief propagation.

## Parameters

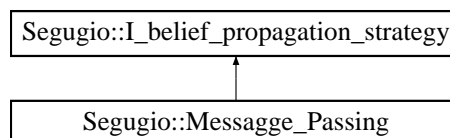
out	<i>diff_to_previous</i>	The difference with respect to the previous message camptation
-----	-------------------------	--

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.32 Segugio::Message\_Passing Class Reference

Inheritance diagram for Segugio::Message\_Passing:



## Public Member Functions

- **bool \_propagate** (std::list< [Node](#) \* > &cluster, const bool &sum\_or\_MAP)

## Additional Inherited Members

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Belief\_propagation.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Belief\_propagation.cpp

## 5.33 Segugio::Node::Neighbour\_connection Struct Reference

### Friends

- class **Node**
- class **I\_belief\_propagation\_strategy**

The documentation for this struct was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Node.cpp

## 5.34 Segugio::Node Class Reference

### Classes

- struct [Neighbour\\_connection](#)
- class [Node\\_factory](#)

*Interface for describing a net: set of nodes representing random variables.*

### Public Member Functions

- [Categoric\\_var](#) \* **Get\_var** ()
- void **Gather\_all\_Unaries** (std::list< [Potential](#) \* > \*result)
- void **Append\_temporary\_permanent\_Unaries** (std::list< [Potential](#) \* > \*result)
- void **Append\_permanent\_Unaries** (std::list< [Potential](#) \* > \*result)
- const std::list< [Neighbour\\_connection](#) \* > \* **Get\_Active\_connections** ()
- void **Compute\_neighbour\_set** (std::list< [Node](#) \* > \*Neigh\_set)
- void **Compute\_neighbour\_set** (std::list< [Node](#) \* > \*Neigh\_set, std::list< [Potential](#) \* > \*binary\_involved)
- void **Compute\_neighbourhood\_messages** (std::list< [Potential](#) \* > \*messages, [Node](#) \*node\_involved\_↵  
in\_connection)

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Node.cpp

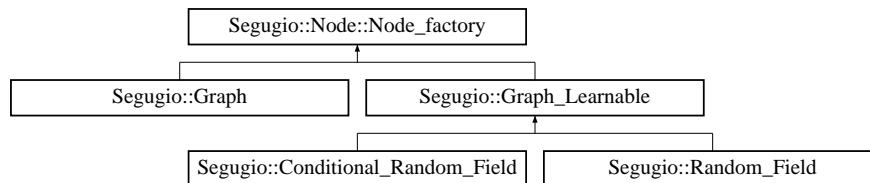


## 5.35 Segugio::Node::Node\_factory Class Reference

Interface for describing a net: set of nodes representing random variables.

```
#include <Node.h>
```

Inheritance diagram for Segugio::Node::Node\_factory:



### Classes

- struct [\\_Baseline\\_4\\_Insertion](#)
- struct [\\_Pot\\_wrapper\\_4\\_Insertion](#)
- class [\\_SubGraph](#)

### Public Member Functions

- [Categoric\\_var \\* Find\\_Variable](#) (const std::string &var\_name)  
*Returns a pointer to the variable in this graph with that name.*
- [Categoric\\_var \\* Find\\_Variable](#) (Categoric\_var \*var\_with\_same\_name)  
*Returns a pointer to the variable in this graph with the same name of the variable passed as input.*
- void [Get\\_Actual\\_Hidden\\_Set](#) (std::list< Categoric\_var \* > \*result)  
*Returns the current set of hidden variables.*
- void [Get\\_Actual\\_Observation\\_Set](#) (std::list< Categoric\_var \* > \*result)  
*Returns the current set of observed variables.*
- void [Get\\_All\\_variables\\_in\\_model](#) (std::list< Categoric\_var \* > \*result)  
*Returns the set of all variable contained in the net.*
- void [Get\\_marginal\\_distribution](#) (std::list< float > \*result, Categoric\_var \*var)  
*Returns the marginal probability of the variable passed  $P(var|model, observations)$ .*
- void [MAP\\_on\\_Hidden\\_set](#) (std::list< size\_t > \*result)  
*Returns the Maximum a Posteriori estimation of the hidden set. .*
- void [Gibbs\\_Sampling\\_on\\_Hidden\\_set](#) (std::list< std::list< size\_t > > \*result, const unsigned int &N\_← samples, const unsigned int &initial\_sample\_to\_skip)  
*Returns a set of samples of the conditional distribution  $P(hidden\ variables\ |\ model, observed\ variables)$ . .*
- unsigned int [Get\\_Iteration\\_4\\_belief\\_propagation](#) ()  
*Returns the current value adopted when performing a loopy belief propagation.*
- void [Set\\_Iteration\\_4\\_belief\\_propagation](#) (const unsigned int &iter\_to\_use)  
*Returns the value to adopt when performing a loopy belief propagation.*
- void [Eval\\_Log\\_Energy\\_function](#) (float \*result, size\_t \*combination, const std::list< Categoric\_var \* > &var\_← \_order\_in\_combination)  
*Returns the logarithmic value of the energy function.*
- void [Eval\\_Log\\_Energy\\_function](#) (float \*result, const std::list< size\_t > &combination, const std::list< Categoric\_var \* > &var\_order\_in\_combination)

Same as [Eval\\_Log\\_Energy\\_function\(float\\* result, size\\_t\\* combination, const std::list< Categorical\\_var\\*> & var\\_order\\_in\\_combination\)](#), passing a list instead of an array size\_t\*, a list<size\_t> for describing the combination for which you want to evaluate the energy.

- void [Eval\\_Log\\_Energy\\_function](#) (std::list< float > \*result, const std::list< size\_t \* > &combinations, const std::list< Categorical\_var \* > &var\_order\_in\_combination)

Same as [Eval\\_Log\\_Energy\\_function\(float\\* result, size\\_t\\* combination, const std::list< Categorical\\_var\\*> & var\\_order\\_in\\_combination\)](#), passing a list of combinations: don't iterate yourself many times using [Eval\\_Log\\_Energy\\_function\(float\\* result, size\\_t\\* combination, const std::list< Categorical\\_var\\*> & var\\_order\\_in\\_combination\)](#) but call this function.

- void [Eval\\_Log\\_Energy\\_function\\_normalized](#) (float \*result, size\_t \*combination, const std::list< Categorical\_var \* > &var\_order\_in\_combination)

Similar as [Eval\\_Log\\_Energy\\_function\(float\\* result, size\\_t\\* combination, const std::list< Categorical\\_var\\*> & var\\_order\\_in\\_combination\)](#), but computing the Energy function normalized:  $E_{norm} = E(Y_1, 2, \dots, n) / \max \text{ possible } \{ E \}$ .  $E_{norm}$  is in  $[0, 1]$ . The logarithmic value of  $E_{norm}$  is actually returned.

- void [Eval\\_Log\\_Energy\\_function\\_normalized](#) (float \*result, const std::list< size\_t > &combination, const std::list< Categorical\_var \* > &var\_order\_in\_combination)

Similar as [Eval\\_Log\\_Energy\\_function\(float\\* result, const std::list<size\\_t> & combination, const std::list< Categorical\\_var\\*> & var\\_order\\_in\\_combination\)](#) but computing the Energy function normalized.

- void [Eval\\_Log\\_Energy\\_function\\_normalized](#) (std::list< float > \*result, const std::list< size\_t \* > &combinations, const std::list< Categorical\_var \* > &var\_order\_in\_combination)

Similar as [Eval\\_Log\\_Energy\\_function\(std::list<float>\\* result, const std::list<size\\_t\\*> & combinations, const std::list< Categorical\\_var\\*> & var\\_order\\_in\\_combination\)](#) but computing the Energy function normalized.

- void [Get\\_Observation\\_Set\\_val](#) (std::list< size\_t > \*result)

Returns the actual values set observations. This function can be invoked after a call to void [Set\\_Observation\\_Set\\_val\(const std::list<size\\_t> &observed\\_vals\)](#)

- void [Get\\_structure](#) (std::list< const Potential \* > \*structure)

Returns the list of potentials constituting the net. Usefull for structural learning.

- size\_t [Get\\_structure\\_size](#) ()

Returns the number of potentials constituting the graph, no matter of their type (simple shape, exponential shape fixed or exponential shape tunable)

## Protected Member Functions

- **Node\_factory** (const bool &use\_cloning\_Insert)
- void **Import\_from\_XML** (XML\_reader \*xml\_data, const std::string &prefix\_config\_xml\_file)
- void **Insert** (\_Pot\_wrapper\_4\_Insertion \*element\_to\_add)
- void **Insert** (std::list< \_Pot\_wrapper\_4\_Insertion \* > &elements\_to\_add)
- virtual \_Pot\_wrapper\_4\_Insertion \* **Get\_Inserter** (Potential\_Exp\_Shape \*pot, const bool &weight\_tunability)
- void **Insert** (Potential\_Shape \*pot)
- void **Insert** (Potential\_Exp\_Shape \*pot, const bool &weight\_tunability)
- Node \* **Find\_Node** (const std::string &var\_name)
- void **Set\_Observation\_Set\_var** (const std::list< Categorical\_var \* > &new\_observed\_vars)
- Set the values for the observations. Must call after calling [Node\\_factory::Set\\_Observation\\_Set\\_val](#).
- void **Set\_Observation\_Set\_val** (const std::list< size\_t > &new\_observed\_vals)
- Set the observation set: which variables are treated like evidence when performing belief propagation.
- void **Belief\_Propagation** (const bool &sum\_or\_MAP)
- size\_t \* **Get\_observed\_val\_in\_case\_is\_in\_observed\_set** (Categorical\_var \*var)

### 5.35.1 Detailed Description

Interface for describing a net: set of nodes representing random variables.

## 5.35.2 Member Function Documentation

### 5.35.2.1 Eval\_Log\_Energy\_function()

```
void Segugio::Node::Node_factory::Eval_Log_Energy_function (
    float * result,
    size_t * combination,
    const std::list< Categorical_var * > & var_order_in_combination )
```

Returns the logarithmic value of the energy function.

Energy function  $E = \text{Pot}_1(Y_1, 2, \dots, n) * \text{Pot}_2(Y_1, 2, \dots, n) \dots * \text{Pot}_m(Y_1, 2, \dots, n)$ . The combinations passed as input must contain values for all the variables present in this graph.

#### Parameters

out	<i>result</i>	
in	<i>combination</i>	set of values in the combination for which the energy function has to be evaluated
in	<i>var_order_in_combination</i>	order of variables considered when assembling combination. They must be references to the variables actually wrapped by this graph.

### 5.35.2.2 Find\_Variable() [1/2]

```
Categorical_var * Segugio::Node::Node_factory::Find_Variable (
    const std::string & var_name )
```

Returns a pointer to the variable in this graph with that name.

Returns NULL when the variable is not present in the graph.

#### Parameters

in	<i>var_name</i>	name to search
----	-----------------	----------------

### 5.35.2.3 Find\_Variable() [2/2]

```
Categorical_var* Segugio::Node::Node_factory::Find_Variable (
    Categorical_var * var_with_same_name ) [inline]
```

Returns a pointer to the variable in this graph with the same name of the variable passed as input.

Returns NULL when the variable is not present in the graph

## Parameters

in	<i>var_with_same_name</i>	variable having the same of name of the variable to search
----	---------------------------	--

## 5.35.2.4 Get\_marginal\_distribution()

```
void Segugio::Node::Node_factory::Get_marginal_distribution (
    std::list< float > * result,
    Categorical_var * var )
```

Returns the marginal probability of the variable passed  $P(\text{var}|\text{model}, \text{observations})$ .

on the basis of the last observations set (see [Node\\_factory::Set\\_Observation\\_Set\\_var](#))

## 5.35.2.5 Gibbs\_Sampling\_on\_Hidden\_set()

```
void Segugio::Node::Node_factory::Gibbs_Sampling_on_Hidden_set (
    std::list< std::list< size_t >> * result,
    const unsigned int & N_samples,
    const unsigned int & initial_sample_to_skip )
```

Returns a set of samples of the conditional distribution  $P(\text{hidden variables} \mid \text{model}, \text{observed variables})$ . .

Samples are obtained through Gibbs sampling. Calculations are done considering the last last observations set (see [Node\\_factory::Set\\_Observation\\_Set\\_var](#))

## Parameters

in	<i>N_samples</i>	number of desired samples
in	<i>initial_sample_to_skip</i>	number of samples to skip for performing Gibbs sampling
out	<i>result</i>	returned samples: every element of the list is a combination of values for the hidden set, with the same order returned when calling <a href="#">Node_factory::Get_Actual_Hidden_Set</a>

## 5.35.2.6 MAP\_on\_Hidden\_set()

```
void Segugio::Node::Node_factory::MAP_on_Hidden_set (
    std::list< size_t > * result )
```

Returns the Maximum a Posteriori estimation of the hidden set. .

Values are ordered as returned by [Node\\_factory::Get\\_Actual\\_Hidden\\_Set](#). Calculations are done considering the last last observations set (see [Node\\_factory::Set\\_Observation\\_Set\\_var](#))

The documentation for this class was generated from the following files:

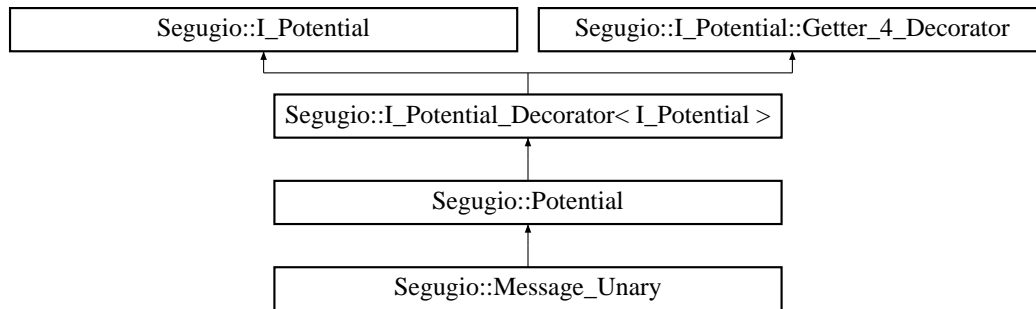
- C:/Users/andre/Desktop/CRF/CRF/Header/Node.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Node.cpp

## 5.36 Segugio::Potential Class Reference

This class is mainly adopted for computing operations on potentials.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::Potential:



### Public Member Functions

- [Potential](#) ([Potential\\_Shape](#) \*pot)
- [Potential](#) ([Potential\\_Exp\\_Shape](#) \*pot)
- [Potential](#) (const std::list< [Potential](#) \* > &potential\_to\_merge, const bool &use\_sparse\_format=true)  
*The potential to create is obtained by merging a set of potentials referring to the same variables (i.e. values in the image are obtained as a product of the ones in the potential\_to\_merge set)*
- [Potential](#) (const std::list< size\_t > &val\_observed, const std::list< [Categoric\\_var](#) \* > &var\_observed, [Potential](#) \*pot\_to\_reduce)  
*The potential to create is obtained by marginalizing the observed variable passed as input.*
- void [Get\\_marginals](#) (std::list< float > \*prob\_distr)  
*Obtain the marginal probabilities of the variables in the domain of this potential, when considering this potential only.*

### Additional Inherited Members

#### 5.36.1 Detailed Description

This class is mainly adopted for computing operations on potentials.

#### 5.36.2 Constructor & Destructor Documentation

##### 5.36.2.1 [Potential\(\)](#) [1/4]

```
Segugio::Potential::Potential (
    Potential\_Shape * pot ) [inline]
```

## Parameters

in	<i>pot</i>	potential shape to wrap
----	------------	-------------------------

## 5.36.2.2 Potential() [2/4]

```
Segugio::Potential::Potential (
    Potential_Exp_Shape * pot ) [inline]
```

## Parameters

in	<i>pot</i>	exponential potential shape to wrap
----	------------	-------------------------------------

## 5.36.2.3 Potential() [3/4]

```
Segugio::Potential::Potential (
    const std::list< Potential * > & potential_to_merge,
    const bool & use_sparse_format = true )
```

The potential to create is obtained by merging a set of potentials referring to the same variables (i.e. values in the image are obtained as a product of the ones in the potential\_to\_merge set)

## Parameters

in	<i>potential_to_merge</i>	list of potential to merge, i.e. compute their product
in	<i>use_sparse_format</i>	when false, the entire domain is allocated even if some values are equal to 0

## 5.36.2.4 Potential() [4/4]

```
Segugio::Potential::Potential (
    const std::list< size_t > & val_observed,
    const std::list< Categorical_var * > & var_observed,
    Potential * pot_to_reduce )
```

The potential to create is obtained by marginalizing the observed variable passed as input.

## Parameters

in	<i>pot_to_reduce</i>	the potential from which the variables observed are marginalized
in	<i>var_observed</i>	variables observed in pot_to_reduce
in	<i>val_observed</i>	values observed (same order of var_observed)

### 5.36.3 Member Function Documentation

#### 5.36.3.1 Get\_marginals()

```
void Segugio::Potential::Get_marginals (
    std::list< float > * prob_distr )
```

Obtain the marginal probabilities of the variables in the domain of this potential, when considering this potential only.

#### Parameters

in	<i>prob_distr</i>	marginals
----	-------------------	-----------

The documentation for this class was generated from the following files:

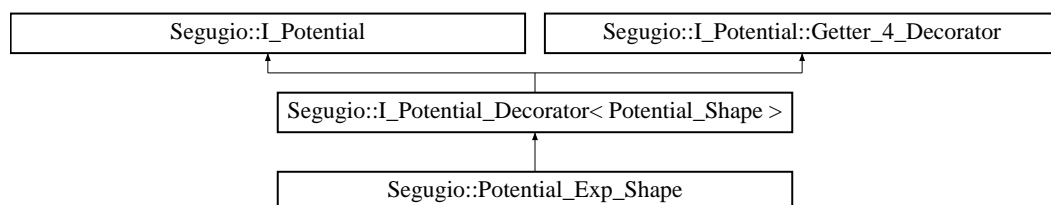
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.37 Segugio::Potential\_Exp\_Shape Class Reference

Represents an exponential potential, wrapping a normal shape one: every value of the domain are assumed as  $\exp(mWeight * val\_in\_shape\_wrapped)$

```
#include <Potential.h>
```

Inheritance diagram for Segugio::Potential\_Exp\_Shape:



### Classes

- struct [Getter\\_weight\\_and\\_shape](#)

## Public Member Functions

- [Potential\\_Exp\\_Shape](#) ([Potential\\_Shape](#) \*shape, const float &w=1.f)  
*When building a new exponential shape potential, all the values of the domain are computed according to the new shape passed as input.*
- [Potential\\_Exp\\_Shape](#) (const std::list< [Categoric\\_var](#) \* > &var\_involved, const std::string &file\_to\_read, const float &w=1.f)  
*When building a new exponential shape potential, all the values of the domain are computed according to the potential shape to wrap, which is instantiated in the constructor by considering the textual file provided, see also [Potential\\_Shape](#)(const std::list<Categoric\_var\*> &var\_involved, const std::string& file\_to\_read)*
- [Potential\\_Exp\\_Shape](#) (const [Potential\\_Exp\\_Shape](#) \*to\_copy, const std::list< [Categoric\\_var](#) \* > &var\_involved)
- void [Substitute\\_variables](#) (const std::list< [Categoric\\_var](#) \* > &new\_var)  
*Use this method for replacing the set of variables this potential must refer. Variables in new\_var must be equal in number to the original set of variables and must have the same sizes.*

## Protected Member Functions

- virtual std::list< [I\\_Distribution\\_value](#) \* > \* [Get\\_distr](#) ()
- void [Wrap](#) ([Potential\\_Shape](#) \*shape)

## Protected Attributes

- float **mWeight**
- std::list< [I\\_Distribution\\_value](#) \* > [Distribution](#)

## Additional Inherited Members

### 5.37.1 Detailed Description

Represents an exponential potential, wrapping a normal shape one: every value of the domain are assumed as  $\exp(\text{mWeight} * \text{val\_in\_shape\_wrapped})$

### 5.37.2 Constructor & Destructor Documentation

#### 5.37.2.1 [Potential\\_Exp\\_Shape\(\)](#) [1/3]

```
Segugio::Potential_Exp_Shape::Potential_Exp_Shape (
    Potential\_Shape * shape,
    const float & w = 1.f )
```

When building a new exponential shape potential, all the values of the domain are computed according to the new shape passed as input.



## Parameters

in	<i>shape</i>	shape distribution to wrap
in	<i>w</i>	weight of the exponential

## 5.37.2.2 Potential\_Exp\_Shape() [2/3]

```
Segugio::Potential_Exp_Shape::Potential_Exp_Shape (
    const std::list< Categorical_var * > & var_involved,
    const std::string & file_to_read,
    const float & w = 1.f )
```

When building a new exponential shape potential, all the values of the domain are computed according to the potential shape to wrap, which is instantiated in the constructor by considering the textual file provided, see also Potential\_Shape(const std::list<Categorical\_var\*>& var\_involved, const std::string& file\_to\_read)

## Parameters

in	<i>var_involved</i>	variables involved in the domain of this variables
in	<i>file_to_read</i>	textual file to read containing the values for the image
in	<i>w</i>	weight of the exponential

## 5.37.2.3 Potential\_Exp\_Shape() [3/3]

```
Segugio::Potential_Exp_Shape::Potential_Exp_Shape (
    const Potential_Exp_Shape * to_copy,
    const std::list< Categorical_var * > & var_involved )
```

Use this constructor for cloning an exponential shape, but considering a different set of variables. Variables in var\_involved must be equal in number to those in the potential to clone and must have the same sizes of the variables involved in the potential to clone.

## Parameters

in	<i>to_copy</i>	shape to clone
in	<i>var_involved</i>	new set of variables to consider when cloning

## 5.37.3 Member Function Documentation

### 5.37.3.1 Substitute\_variables()

```
void Segugio::Potential_Exp_Shape::Substitute_variables (
    const std::list< Categorical_var * > & new_var ) [inline]
```

Use this method for replacing the set of variables this potential must refer. Variables in `new_var` must be equal in number to the original set of variables and must have the same sizes.

#### Parameters

<code>in</code>	<code>new_var</code>	variables to consider for the substitution
-----------------	----------------------	--

## 5.37.4 Member Data Documentation

### 5.37.4.1 Distribution

```
std::list<I_Distribution_value*> Segugio::Potential_Exp_Shape::Distribution [protected]
```

Weight assumed for modulating the exponential (see description of the class)

The documentation for this class was generated from the following files:

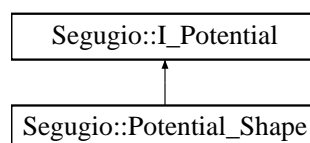
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.38 Segugio::Potential\_Shape Class Reference

It's the only possible concrete potential. It contains the domain and the image of the potential.

```
#include <Potential.h>
```

Inheritance diagram for Segugio::Potential\_Shape:



## Public Member Functions

- [Potential\\_Shape](#) (const std::list< [Categoric\\_var](#) \* > &var\_involved)  
*When building a new shape potential, all values of the image are assumed as all zeros.*
- [Potential\\_Shape](#) (const std::list< [Categoric\\_var](#) \* > &var\_involved, const std::string &file\_to\_read)
- [Potential\\_Shape](#) (const std::list< [Categoric\\_var](#) \* > &var\_involved, const bool &correlated\_or\_not)  
*Returns simple correlating or anti\_correlating shapes. .*
- [Potential\\_Shape](#) (const [Potential\\_Shape](#) \*to\_copy, const std::list< [Categoric\\_var](#) \* > &var\_involved)
- [Potential\\_Shape](#) (const [Potential\\_Shape](#) &to\_copy)
- void [Import](#) (const std::string &file\_to\_read)  
*For populating the image of the domain with the values reported in the textual file.*
- void [Add\\_value](#) (const std::list< size\_t > &new\_indeces, const float &new\_val)  
*Add a new value in the image set.*
- void [Set\\_ones](#) ()  
*All values in the image of the domain are set to 1.*
- void [Set\\_random](#) (const float zeroing\_threashold=1.f)  
*All values in the image of the domain are randomly set.*
- void [Normalize\\_distribution](#) ()  
*All values in the image of the domain are multiplied by a scaling factor, in order to to have maximal value equal to 1. Exploited for computing messages.*
- void [Substitute\\_variables](#) (const std::list< [Categoric\\_var](#) \* > &new\_var)  
*Use this method for replacing the set of variables this potential must refer. Variables in new\_var must be equal in number to the original set of variables and must have the same sizes.*

## Protected Member Functions

- void [Check\\_add\\_value](#) (const std::list< size\_t > &indices)
- virtual const std::list< [Categoric\\_var](#) \* > \* [Get\\_involved\\_var](#) () const
- virtual std::list< [I\\_Distribution\\_value](#) \* > \* [Get\\_distr](#) ()

## Additional Inherited Members

### 5.38.1 Detailed Description

It's the only possible concrete potential. It contains the domain and the image of the potential.

### 5.38.2 Constructor & Destructor Documentation

#### 5.38.2.1 Potential\_Shape() [1/4]

```
Segugio::Potential_Shape::Potential_Shape (
    const std::list< Categoric\_var * > & var_involved )
```

When building a new shape potential, all values of the image are assumed as all zeros.

## Parameters

in	<i>var_involved</i>	variables involved in the domain of this variables
----	---------------------	--

## 5.38.2.2 Potential\_Shape() [2/4]

```
Segugio::Potential_Shape::Potential_Shape (
    const std::list< Categorical_var * > & var_involved,
    const std::string & file_to_read )
```

## Parameters

in	<i>var_involved</i>	variables involved in the domain of this variables
in	<i>file_to_read</i>	textual file to read containing the values for the image

## 5.38.2.3 Potential\_Shape() [3/4]

```
Segugio::Potential_Shape::Potential_Shape (
    const std::list< Categorical_var * > & var_involved,
    const bool & correlated_or_not )
```

Returns simple correlating or anti\_correlating shapes. .

A simple correlating shape is a distribution having a value of 1 for every combinations {0,0,...,0}; {1,1,...,1} etc. and 0 for all other combinations. A simple anti\_correlating shape is a distribution having a value of 0 for every combinations {0,0,...,0}; {1,1,...,1} etc. and 1 for all other combinations.

## Parameters

in	<i>var_involved</i>	variables involved in the domain of this variables: they must have all the same size
in	<i>correlated_or_not</i>	when true produce a simple correlating shape, when false produce a anti_correlating function

## 5.38.2.4 Potential\_Shape() [4/4]

```
Segugio::Potential_Shape::Potential_Shape (
    const Potential_Shape * to_copy,
    const std::list< Categorical_var * > & var_involved )
```

Use this constructor for cloning a shape, but considering a different set of variables. Variables in var\_involved must be equal in number to those in the potential to clone and must have the same sizes of the variables involved in the potential to clone.

## Parameters

in	<i>to_copy</i>	shape to clone
in	<i>var_involved</i>	new set of variables to consider when cloning

## 5.38.3 Member Function Documentation

## 5.38.3.1 Add\_value()

```
void Segugio::Potential_Shape::Add_value (
    const std::list< size_t > & new_indeces,
    const float & new_val )
```

Add a new value in the image set.

## Parameters

in	<i>new_indices</i>	combination related to the new value to add for the image
in	<i>new_val</i>	new val to insert

## 5.38.3.2 Import()

```
void Segugio::Potential_Shape::Import (
    const std::string & file_to_read )
```

For populating the image of the domain with the values reported in the textual file.

## Parameters

in	<i>file_to_read</i>	textual file to read containing the values for the image
----	---------------------	--

## 5.38.3.3 Substitute\_variables()

```
void Segugio::Potential_Shape::Substitute_variables (
    const std::list< Categorical_var * > & new_var )
```

Use this method for replacing the set of variables this potential must refer. Variables in new\_var must be equal in number to the original set of variables and must have the same sizes.

## Parameters

in	new_var	variables to consider for the substitution
----	---------	--

The documentation for this class was generated from the following files:

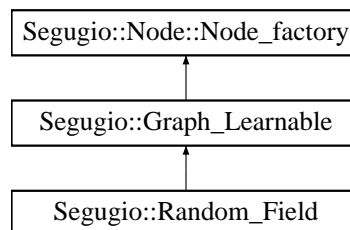
- C:/Users/andre/Desktop/CRF/CRF/Header/Potential.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Potential.cpp

## 5.39 Segugio::Random\_Field Class Reference

This class describes a generic Random Field, not having a particular set of variables observed.

```
#include <Graphical_model.h>
```

Inheritance diagram for Segugio::Random\_Field:



### Public Member Functions

- [Random\\_Field](#) (const bool &use\_cloning\_Insert=true)  
*empty constructor*
- [Random\\_Field](#) (const std::string &config\_xml\_file, const std::string &prefix\_config\_xml\_file="")  
*The model is built considering the information contained in an xml configuration file. .*
- [Random\\_Field](#) (const std::list< [Potential\\_Exp\\_Shape](#) \* > &potentials\_exp, const bool &use\_cloning\_↔ Insert=true, const std::list< bool > &tunable\_mask={}, const std::list< [Potential\\_Shape](#) \* > &shapes={})  
*This constructor initializes the graph with the specified potentials passed as input.*
- void [Insert](#) ([Potential\\_Shape](#) \*pot)  
*Similar to [Graph::Insert\(Potential\\_Shape\\* pot\)](#)*
- void [Insert](#) ([Potential\\_Exp\\_Shape](#) \*pot, const bool &is\_weight\_tunable=true)  
*Similar to [Graph::Insert\(Potential\\_Exp\\_Shape\\* pot\)](#).*
- void [Set\\_Observation\\_Set\\_var](#) (const std::list< [Categoric\\_var](#) \* > &new\_observed\_vars)  
*see [Node::Node\\_factory::Set\\_Observation\\_Set\\_var\(const std::list<Categoric\\_var\\*> & new\\_observed\\_vars\)](#)*
- void [Set\\_Observation\\_Set\\_val](#) (const std::list< size\_t > &new\_observed\_vals)  
*see [Node::Node\\_factory::Set\\_Observation\\_Set\\_val\(const std::list<size\\_t> & new\\_observed\\_vals\)](#)*

### Additional Inherited Members

#### 5.39.1 Detailed Description

This class describes a generic Random Field, not having a particular set of variables observed.

## 5.39.2 Constructor & Destructor Documentation

### 5.39.2.1 Random\_Field() [1/3]

```
Segugio::Random_Field::Random_Field (
    const bool & use_cloning_Insert = true ) [inline]
```

empty constructor

#### Parameters

in	<i>use_cloning_Insert</i>	when is true, every time an Insert of a novel potential is called, a copy of that potential is actually inserted. Otherwise, the passed potential is inserted as is: this can be dangerous, cause that potential can be externally modified, but the construction of a novel graph is faster.
----	---------------------------	---

### 5.39.2.2 Random\_Field() [2/3]

```
Segugio::Random_Field::Random_Field (
    const std::string & config_xml_file,
    const std::string & prefix_config_xml_file = "" )
```

The model is built considering the information contained in an xml configuration file. .

See Section 2 of the documentation for the syntax to adopt.

#### Parameters

in	<i>configuration</i>	file
in	<i>prefix</i>	to use. The file prefix_config_xml_file/config_xml_file is searched.

### 5.39.2.3 Random\_Field() [3/3]

```
Segugio::Random_Field::Random_Field (
    const std::list< Potential_Exp_Shape * > & potentials_exp,
    const bool & use_cloning_Insert = true,
    const std::list< bool > & tunable_mask = {},
    const std::list< Potential_Shape * > & shapes = {} )
```

This constructor initializes the graph with the specified potentials passed as input.

## Parameters

in	<i>potentials_exp</i>	the initial set of exponential potentials to insert (can be empty)
in	<i>use_cloning_Insert</i>	when is true, every time an Insert of a novel potential is called (this includes the passed potentials), a copy of that potential is actually inserted. Otherwise, the passed potential is inserted as is: this can be dangerous, cause that potential can be externally modified, but the construction of a novel graph is faster.
in	<i>tunable_mask</i>	when passed as non default value, it must have the same size of potentials. Every value in this list is true if the corresponding potential in the potentials list is tunable, i.e. has a weight whose value can vary with learning
in	<i>shapes</i>	A list of additional non learnable potentials to insert in the model

## 5.39.3 Member Function Documentation

## 5.39.3.1 Insert()

```
void Segugio::Random_Field::Insert (
    Potential_Exp_Shape * pot,
    const bool & is_weight_tunable = true ) [inline]
```

Similar to [Graph::Insert\(Potential\\_Exp\\_Shape\\* pot\)](#).

## Parameters

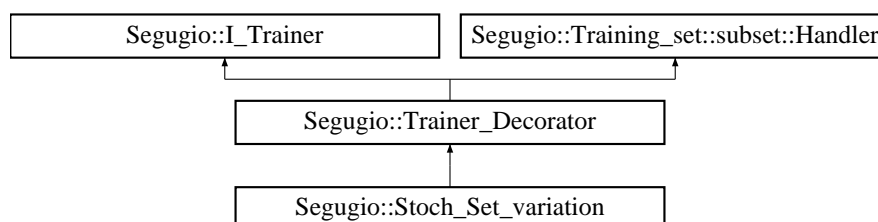
in	<i>is_weight_tunable</i>	When true, you are specifying that this potential has a weight learnable, otherwise the value of the weight is assumed constant.
----	--------------------------	--

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Graphical\_model.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.40 Segugio::Stoch\_Set\_variation Class Reference

Inheritance diagram for Segugio::Stoch\_Set\_variation:





## Public Member Functions

- **Stoch\_Set\_variation** ([Advancer\\_Concrete](#) \*\_to\_wrap, const float &percentage\_to\_use)
- void **Train** ([Graph\\_Learnable](#) \*model\_to\_train, [Training\\_set](#) \*Train\_set, const unsigned int &Max\_Iterations, std::list< float > \*descend\_story)

## Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.41 Segugio::Training\_set::subset Struct Reference

This class is describes a portion of a training set, obtained by sampling values in the original set. Mainly used by stochastic gradient computation strategies.

```
#include <Training_set.h>
```

## Classes

- struct [Handler](#)

## Public Member Functions

- [subset](#) ([Training\\_set](#) \*set, const float &size\_percentage=1.f)

### 5.41.1 Detailed Description

This class is describes a portion of a training set, obtained by sampling values in the original set. Mainly used by stochastic gradient computation strategies.

### 5.41.2 Constructor & Destructor Documentation

#### 5.41.2.1 subset()

```
Segugio::Training_set::subset::subset (
    Training\_set * set,
    const float & size_percentage = 1.f )
```

## Parameters

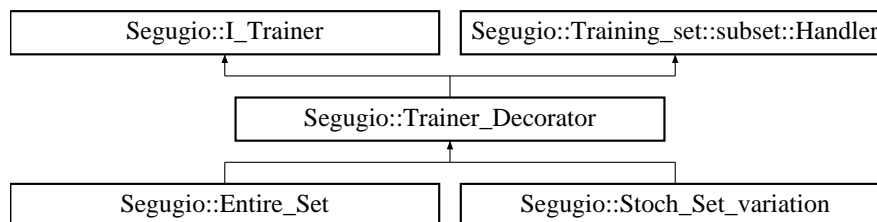
in	<i>set</i>	the training set from which this subset must be extracted
in	<i>size_percentage</i>	percentage to use for the extraction

The documentation for this struct was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Training\_set.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Training\_set.cpp

## 5.42 Segugio::Trainer\_Decorator Class Reference

Inheritance diagram for Segugio::Trainer\_Decorator:



### Public Member Functions

- **Trainer\_Decorator** ([Advancer\\_Concrete](#) \*to\_wrap)
- void **Clean\_Up** ()

### Protected Member Functions

- void **\_\_check\_tunable\_are\_present** ([Graph\\_Learnable](#) \*model\_to\_train)

### Protected Attributes

- [Advancer\\_Concrete](#) \* **Wrapped**

### Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Trainer.cpp

## 5.43 Segugio::Training\_set Class Reference

This class is used for describing a training set for a graph.

```
#include <Training_set.h>
```

## Classes

- class [Basic\\_Extractor](#)  
*Basic extractor, see `Training_set(const std::list<std::string> & variable_names, std::list<Array> samples, I_Extractor<Array>* extractor)`*
- class [I\\_Extractor](#)  
*This class is adopted for parsing a set of samples to import as a novel training set. You have to derive your custom extractor, implementing the two virtual method.*
- struct [subset](#)  
*This class describes a portion of a training set, obtained by sampling values in the original set. Mainly used by stochastic gradient computation strategies.*

## Public Member Functions

- [Training\\_set](#) (const std::string &file\_to\_import)
- template<typename Array >  
[Training\\_set](#) (const std::list< std::string > &variable\_names, std::list< Array > &samples, [I\\_Extractor](#)< Array > \*extractor)  
*Similar to `Training_set(const std::string& file_to_import),.`*
- template<typename Array >  
[Training\\_set](#) (const std::list< [Categoric\\_var](#) \* > &variable\_in\_the\_net, std::list< Array > &samples, [I\\_Extractor](#)< Array > \*extractor)  
*Same as `Training_set(const std::list<std::string> & variable_names, std::list<Array> samples, I_Extractor<Array>* extractor)` passing the variables involved instead of the names.*
- void [Print](#) (const std::string &file\_name)  
*This training set is reprinted in the location specified.*

### 5.43.1 Detailed Description

This class is used for describing a training set for a graph.

A set is described in a textual file, where the first row must contain the list of names of the variables (all the variables) constituting a graph. All other rows are a single sample of the set, reporting the values assumed by the variables, with the order described by the first row

### 5.43.2 Constructor & Destructor Documentation

#### 5.43.2.1 [Training\\_set\(\)](#) [1/2]

```
Segugio::Training_set::Training_set (
    const std::string & file_to_import )
```

#### Parameters

in	<i>file_to_import</i>	file containing the set to import
----	-----------------------	-----------------------------------

### 5.43.2.2 Training\_set() [2/2]

```
template<typename Array >
Segugio::Training_set::Training_set (
    const std::list< std::string > & variable_names,
    std::list< Array > & samples,
    I_Extractor< Array > * extractor ) [inline]
```

Similar to [Training\\_set\(const std::string& file\\_to\\_import\)](#),.

with the difference that the training set is not read from a textual file but it is imported from a list of container (generic can be list, vector or other) describing the samples of the set. You have to derive your own extractor for managing your particular container. [Basic\\_Extractor](#) is a baseline extractor that can be used for all those types having the method `size()` and the operator `[]`.

#### Parameters

in	<i>variable_names</i>	the ordered list of variables to assume for the samples
in	<i>samples</i>	the list of generic Array representing the samples of the training set
in	<i>extractor</i>	the particular extractor to use, see <a href="#">I_Extractor</a>

## 5.43.3 Member Function Documentation

### 5.43.3.1 Print()

```
void Segugio::Training_set::Print (
    const std::string & file_name )
```

This training set is reprinted in the location specified.

#### Parameters

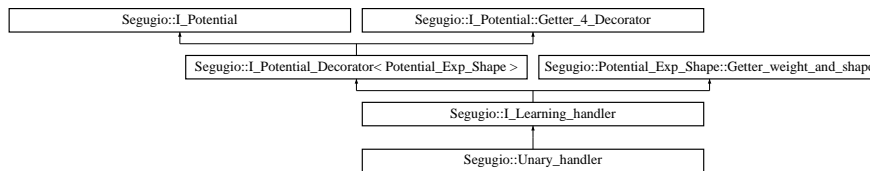
in	<i>file_name</i>	is the path of the file where the set must be printed
----	------------------	---

The documentation for this class was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Training\_set.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Training\_set.cpp

## 5.44 Segugio::Unary\_handler Class Reference

Inheritance diagram for Segugio::Unary\_handler:



## Public Member Functions

- **Unary\_handler** ([Node](#) \*N, [Potential\\_Exp\\_Shape](#) \*pot\_to\_handle)

## Additional Inherited Members

The documentation for this class was generated from the following file:

- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp

## 5.45 Segugio::Graph\_Learnable::Weights\_Manager Struct Reference

### Static Public Member Functions

- static void [Get\\_tunable\\_w](#) (std::list< float > \*w, [Graph\\_Learnable](#) \*model)  
*Returns the values of the tunable weights, those that can vary when learning the model.*

### Friends

- class **I\_Trainer**

The documentation for this struct was generated from the following files:

- C:/Users/andre/Desktop/CRF/CRF/Header/Graphical\_model.h
- C:/Users/andre/Desktop/CRF/CRF/Source/Graphical\_model.cpp



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