

Note on binding of match-seeking and match-repelling particles

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Binding between two primitive particles through match-seeking particle

Let us consider two V -particles which are not composite – they are given with their semantic signatures respectively:

$$\begin{aligned} \text{ssig}(V') &= [\mathbf{p}'_0 \ \mathbf{a}'_{0,1} \ \mathbf{p}'_1 \ \mathbf{p}'_0 \ \mathbf{a}'_{0,2} \ \mathbf{p}'_2 \ \mathbf{p}'_0 \ \mathbf{a}'_{0,3} \ \mathbf{p}'_3 \ \dots \ \mathbf{p}'_i \ \mathbf{a}'_{i,n} \ \mathbf{p}'_n] \\ \text{ssig}(V'') &= [\mathbf{p}''_0 \ \mathbf{a}''_{0,1} \ \mathbf{p}''_1 \ \mathbf{p}''_0 \ \mathbf{a}''_{0,2} \ \mathbf{p}''_2 \ \mathbf{p}''_0 \ \mathbf{a}''_{0,3} \ \mathbf{p}''_3 \ \dots \ \mathbf{p}''_j \ \mathbf{a}''_{j,m} \ \mathbf{p}''_m] \end{aligned}$$

Here each of the quantities \mathbf{p} denotes the property signature vector of the corresponding property P of the V particle. The matrix $\mathbf{a}_{r,s}$ represents the property association particle $A_{r,s}$ which binds to a pair of properties P_r and P_s in the property graph \mathcal{P} of the V particle. Also there is a semantic significance vector $\mathbf{w}_{r,s}$ which is associated the property association particle (a.k.a link) $A_{r,s}$. For details refer to [The Signature of Semantic Structures](#).

Match-seeking particle MA binds to a subgraph \mathcal{S} of the property graph \mathcal{P} of the V particle.

There is a closeness condition which needs to be obeyed in order the particle MA to bind to the particle V .

Binding matrix of a match-seeking particle

The match-seeking particle MA exposes a binding matrix $\text{mbind}(MA)$:

$$\text{mbind}(MA) = [\mathbf{B}^1 \ \mathbf{B}^2 \ \mathbf{B}^3 \ \dots \ \mathbf{B}^q]$$

$$\mathbf{B}^1 = [\mathbf{p}^0 \ \mathbf{a}^{0,1} \ \mathbf{p}^1], \mathbf{B}^2 = [\mathbf{p}^0 \ \mathbf{a}^{0,2} \ \mathbf{p}^2], \mathbf{B}^3 = [\mathbf{p}^0 \ \mathbf{a}^{0,3} \ \mathbf{p}^3], \dots, \mathbf{B}^q = [\mathbf{p}^p \ \mathbf{a}^{p,q} \ \mathbf{p}^q]$$

Obviously, each of the blocks \mathbf{B}^i is $N \times 4$ matrix where N is the dimension of semantic space. From now on we will denote these blocks of any match-seeking particle as *binding elements* B^i of the match-seeking particle M . Each binding element B^i of a match-seeking particle consists of a couple of property particles P^a and P^b connected with association particle $A^{a,b}$. Each binding element B^i is represented by its binding matrix \mathbf{B}^i and its semantic significance vector \mathbf{w}^i .

Note that in each of those blocks having the general form $\mathbf{B}^i = [\mathbf{p}^p \ \mathbf{a}^{p,q} \ \mathbf{p}^q]$ it is possible to have $\mathbf{a}^{p,q} = \mathbf{p}^q = \mathbf{0}$ where $\mathbf{0}$ represents the null vector in semantic space. However, \mathbf{p}^p is never close to the null vector i.e. $|\mathbf{p}^p| > \mathbf{0}$.

Binding of match-seeking particle against V -particle formulated as optimization problem

Let a primitive particle V has the following semantic signature:

$$\text{ssig}(V) = [\mathbf{B}_1 \ \mathbf{B}_2 \ \dots \ \mathbf{B}_m]$$

Let us denote by f_j^i the semantic distance between the binding element B^i of MA and the semantic element B_j of V

$$f_j^i = \text{sdist}(B^i, B_j), \mathbf{B}^i = [\mathbf{p}^p \ \mathbf{a}^{p,q} \ \mathbf{p}^q], \mathbf{B}_j = [\mathbf{p}_r \ \mathbf{a}_{r,s} \ \mathbf{p}_s]$$

Then we define the following metric:

$$\text{sdist}(B^i, B_j) = |\mathbf{p}^p| \text{sdist}(P^p, P_r) + |\mathbf{p}^p| |\mathbf{p}^q| \text{sdist}(A^{p,q}, A_{k,l}) + |\mathbf{p}^q| \text{sdist}(P^q, P_s)$$

where

$$sdist(P^p, P_r) = |\mathbf{p}^p - \mathbf{p}_r|, \quad sdist(P^q, P_s) = |\mathbf{p}^q - \mathbf{p}_s|$$

$$sdist(A^{p,q}, A_{r,s}) = |\mathbf{w}^{p,q} - \mathbf{w}_{r,s}| \times sdist(\mathbf{a}^{p,q}, \mathbf{a}_{r,s})$$

The semantic distance of two matrices \mathbf{a} and \mathbf{b} , having the same number of columns, is given with:

$$sdist(\mathbf{a}, \mathbf{b}) = \sum_{i=1}^n |\vec{\mathbf{a}}_i - \vec{\mathbf{b}}_i| \text{ where } \mathbf{a} = [\vec{\mathbf{a}}_1 \vec{\mathbf{a}}_2 \dots \vec{\mathbf{a}}_n] \text{ and } \mathbf{b} = [\vec{\mathbf{b}}_1 \vec{\mathbf{b}}_2 \dots \vec{\mathbf{b}}_n].$$

Notice that if B^i is incomplete that is – contains only a single property not connected to anything then $sdist(B^i, B_j)$ becomes simply the semantic distance between its sole property particle of the binding element B^i and the corresponding property of the semantic element B_j .

//TODO: finish the optimization problem formulation

Closeness condition for a bind between match seeking particle and primitive semantic particle

Let us denote by $sfil(MA, V)$ the following diagonal matrix which will be named *Filter matrix* of the match seeking particle:

$$sfil(MA, V) = \begin{bmatrix} I_1 & & & & \\ & 0 & & & \\ & & I_2 & & \\ & & & 0 & \\ & & & & \ddots \\ & & & & & I_k \end{bmatrix}$$

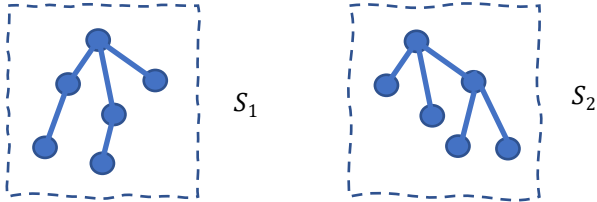
Here $I_i, i = 1, 2, \dots, k$ are identity matrices which represent the regions of interest in the semantic signature matrix of V to the match seeking particle MA .

The regions of interest $sreg(MA, V)$ in the semantic signature of V are obtained by multiplying $sfil(MA, V)$ with $ssig(V)$:

$$sreg(MA, V) = sfil(MA, V) \times ssig(V)$$

Between two semantic structures

Let us have two semantic structures S_1 and S_2 .



Let the semantic signature of S_1 is given with:

$$ssig(S_1) = [\mathbf{V}_1 \mathbf{A}_{1,2} \mathbf{V}_2 \mathbf{A}_{1,3} \mathbf{V}_3 \dots \mathbf{A}_{r,p} \mathbf{V}_p]$$

and the semantic signature of S_2 is given with:

Between a primitive V particle and a semantic structure S