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

D. Gueorguiev 11/7/2021

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:

$ssig(V') = [\boldsymbol{p}'_0 \ \ \boldsymbol{a}'_{0,1} \ \ \boldsymbol{p}'_1 \ \ \boldsymbol{p}'_0 \ \ \boldsymbol{a}'_{0,2} \ \ \boldsymbol{p}'_2 \ \ \boldsymbol{p}'_0 \ \ \boldsymbol{a}'_{0,3} \ \ \boldsymbol{p}'_3 \ \ \dots \ \ \boldsymbol{p}'_i \ \ \boldsymbol{a}'_{i,n} \ \ \boldsymbol{p}'_n]$

$ssig(V'') = [\boldsymbol{p}''_0 \ \ \boldsymbol{a}''_{0,1} \ \ \boldsymbol{p}''_1 \ \ \boldsymbol{p}''_0 \ \ \boldsymbol{a}''_{0,2} \ \ \boldsymbol{p}''_2 \ \ \boldsymbol{p}''_0 \ \ \boldsymbol{a}''_{0,3} \ \ \boldsymbol{p}''_3 \ \ \dots \ \ \boldsymbol{p}''_j \ \ \boldsymbol{a}''_{j,m} \ \ \boldsymbol{p}''_m]$

Here each of the quantities $\boldsymbol{p}$ denotes the property signature vector of the corresponding property P of the V particle. The vector $\boldsymbol{a}_{r,s}$ denotes the signature of 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.

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 $mbind(MA)$:

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

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

Obviously, each of the blocks $\mathbf{B}^i$ is $N \times 3$ matrix where N is the dimension of semantic space. From now on we will denote the block matrices $\mathbf{B}^i$ as *binding elements* of the match-seeking particle M.

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

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

Let a primitive particle V has the following semantic signature:

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

Let us denote by f_j^i the semantic distance between the binding element $\mathbf{B}^i$ of MA and the semantic element $\mathbf{B}_j$ of V

$f_j^i = \|\mathbf{B}^i \ominus \mathbf{B}_j\| \,, \mathbf{B}^i = [\boldsymbol{p}^p \ \ \boldsymbol{a}^{p,q} \ \ \boldsymbol{p}^q], \mathbf{B}_j = [\boldsymbol{p}_r \ \ \boldsymbol{a}_{r,s} \ \ \boldsymbol{p}_s]$

Here the operation $\|\ominus\|$ denotes the following metric:

$\|\mathbf{B}^i \ominus \mathbf{B}_j\| = |\boldsymbol{p}^p||\boldsymbol{p}^p - \boldsymbol{p}_r| + |\boldsymbol{a}^{p,q}||\boldsymbol{a}^{p,q} - \boldsymbol{a}_{r,s}| + |\boldsymbol{p}^q||\boldsymbol{p}^q - \boldsymbol{p}_s|$

We also use the operation $\circledast$ to denote columnar dot product defined as:

$\mathbf{B}^i \circledast \mathbf{B}_j = \boldsymbol{p}^p \cdot \boldsymbol{p}_r + \boldsymbol{a}^{p,q} \cdot \boldsymbol{a}_{r,s} + \boldsymbol{p}^q \cdot \boldsymbol{p}_s$

TODO: finish this

Recursive definition of the semantic distance?

$f_j^i(B) = \|\mathbf{B}^i \ominus \mathbf{B}_j\|, \ f_q^p(a) = \|\boldsymbol{a}^p \ominus \boldsymbol{a}_q\|, \ f_s^r(w) = \|\boldsymbol{w}^r \ominus \boldsymbol{w}_s\|$

Here $\boldsymbol{w} \subset \ \boldsymbol{a} \subset \mathbf{B}$.

$$f_j^i(B) = |\boldsymbol{p}^p||\boldsymbol{p}^p - \boldsymbol{p}_r| + |\boldsymbol{a}^{p,q}|\, f_{r,s}^{p,q}(a) + f_{r,s}^{p,q}(w)|\boldsymbol{p}^q||\boldsymbol{p}^q - \boldsymbol{p}_s|$$

In abbreviated form:

$$f(B) = |\boldsymbol{p}^1||\boldsymbol{p}^1 - \boldsymbol{p}_1| + |\boldsymbol{a}^{1,2}|\, f(a) + f(w)|\boldsymbol{p}^2||\boldsymbol{p}^2 - \boldsymbol{p}_2|$$

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:

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

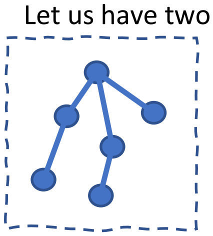
Here $I_i, i = 1,2, \dots, k$ are identity matrices which represent the regions of interest in the semantic signature matrix of V to the match seeking particle MA.

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

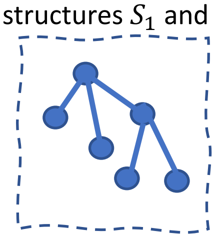
$$sreg(MA,V) = sfil(MA,V) \times ssig(V)$$

Between two semantic structures

Let us have two semantic structures S_1 and S_2.



S_1



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