The Signature of Semantic Structures

Let us have the compound particle V_{comp} represented by its elementary particle sequence and semantic tree $stree(V_{comp})$:

$stree(V_{comp}) =$

```
          __V1__
        /   |    \
      V2    V5   _V6_
     /  \        / | \
    V3   V4    V7  V8  V9
```

The property tree for each V-particle $V_k, k = 1..9$ are given with the algebraic notation discussed in Semantic Tree Operations.

$ptree(V_k) \ = \ \sum_{\boldsymbol{k} \in \mathfrak{T}(V_k), i \in \mathbb{p}(V_k)} (\boldsymbol{k}, P_i)$. Here $\boldsymbol{k}$ denotes the path $(k_{l_1}, k_{l_2}, \dots, k_{l_h})$ constructed by branching consecutively along the k_{l_1}-*th* branch from the top level, then the k_{l_2}-th branch from the lower level and finally k_{l_h}-th branch from the h-th level. The set $\mathfrak{T}(V_k)$ denotes the set of all paths from the root to a leaf in the property tree of V_k. The set $\mathbb{p}(V_k)$ denotes the indices of the vertices in the property tree of V_k.

```
      V1                          V2 `                  ...        V9

  P1 P2  P3                 P1--- o ---P2                     P1--- o ---P2
    \ | /  ..                    / | \
Pk --- o --- Pi                P3  P4  P5_
  ..  / | \  ..               / \       |  \
  Pj+1 Pj  Pj-1             P6   P7     P8   P9
                            |
                            P10
```

Expressing the property tree of V_1 with the algebraic notation discussed earlier:

$ptree(V_1) \ = \ \sum_{k_j \in \mathfrak{T}(V_1), i \in \mathbb{p}(V_1)} (k_j, P_j)$

Similarly, $ptree(V_2)$ is given with

$$ptree(V_2) = (1, P_0) + (k_1, P_1) + (k_2, P_2) + (k_3, P_3) + (k_4, P_4) + (k_5, P_5) + (k_3 k_1, P_6) + (k_3 k_2, P_7) + (k_5 k_1, P_8) + (k_5 k_2, P_9) + (k_3 k_1 k_1, P_{10})$$

Here P_0 is $text(V_2)$.

Now if we expand the property trees for each V-particle in the semantic tree for the composite particle V_{comp} we will have a larger augmented property tree. This augmented property tree represents the semantic structure of V_{comp} and can be recorded in a matrix form which is the semantic signature of V_{comp}. The semantic signature matrix of V_{comp} will have the following structure:

$$ssig(V_{comp}) = [\boldsymbol{p_0} \ \ \boldsymbol{a_{0,1}} \ \ \boldsymbol{p_1} \ \ \boldsymbol{p_0} \ \ \boldsymbol{a_{0,2}} \ \ \boldsymbol{p_2} \ \ \boldsymbol{p_0} \ \ \boldsymbol{a_{0,3}} \ \ \boldsymbol{p_3} \ \ \dots \ \ \boldsymbol{p_p} \ \ \boldsymbol{a_{p,q}} \ \ \boldsymbol{p_q}]$$

The last matrix can be rewritten in block matrix notation:

$$ssig(V_{comp}) = [\boldsymbol{B_1}\ \boldsymbol{B_2}\ \boldsymbol{B_3}\ \ \dots\ \ \boldsymbol{B_q}]$$

$$\boldsymbol{B_1} = [\boldsymbol{p_0}\ \ \boldsymbol{a_{0,1}}\ \ \boldsymbol{p_1}]\ ,\ \boldsymbol{B_2} = [\boldsymbol{p_0}\ \ \boldsymbol{a_{0,2}}\ \ \boldsymbol{p_2}]\ ,\ \boldsymbol{B_3} = [\boldsymbol{p_0}\ \ \boldsymbol{a_{0,2}}\ \ \boldsymbol{p_3}]\ , \dots,\ \boldsymbol{B_q} = [\boldsymbol{p_0}\ \ \boldsymbol{a_{0,2}}\ \ \boldsymbol{p_q}]$$

Here the block matrix $\boldsymbol{B_1}$fully describes the property P_1 including how it is connected to the property tree $ptree(V_1)$. Similarly, $\boldsymbol{B_2}$ and $\boldsymbol{B_3}$ fully describes the properties P_2 and P_3 and their connectivity to $ptree(V_1)$. Finally, $\boldsymbol{B_q}$ fully describes the property $P_q$and its connectivity to $ptree(V_9)$.

In the block matrix for $ssig(V_{comp})$ $\boldsymbol{p_0}$ denotes the signature column vector of the property P_0 , $\boldsymbol{a_{0,1}}$denotes the signature column vector of the arc between property P_0 and property P_1, $\boldsymbol{a_{p,q}}$ denotes the signature column vector of the arc between property $P_p$and P_q. Let us denote the number of rows of $ssig(V_{comp})$ by N and the number of columns by M.
The semantic signature matrix $ssig(V_{comp})$ can be decomposed as a sum of two intrinsic structural matrices – property signature matrix $psig(V_{comp})$ and connectivity signature matrix $csig(V_{comp})$:

$$ssig(V_{comp}) = psig(V_{comp}) + csig(V_{comp})$$

$$psig(V_{comp}) = [\boldsymbol{p_0}\ \ 0\ \ \boldsymbol{p_1}\ \ \boldsymbol{p_0}\ \ 0\ \ \boldsymbol{p_2}\ \ \boldsymbol{p_0}\ \ 0\ \ \boldsymbol{p_3}\ \ \dots\ \ \boldsymbol{p_p}\ \ \ 0\ \ \ \boldsymbol{p_q}]$$

$$csig(V_{comp}) = [0\ \ \boldsymbol{a_{0,1}}\ \ 0\ \ 0\ \ \boldsymbol{a_{0,2}}\ \ 0\ \ 0\ \ \boldsymbol{a_{0,3}}\ \ 0\ \ \dots\ \ 0\ \ \ \boldsymbol{a_{p,q}}\ \ \ 0]$$

Let us denote by $psig(P_1, V_{comp})$ the augmented semantic property signature of property $P_1$with respect to V_{comp}. It is given with:

$$psig(P_0, V_{comp}) = [\boldsymbol{p_0}\ \ 0\ \ 0\ \ \boldsymbol{p_0}\ \ 0\ \ 0\ \ \boldsymbol{p_0}\ \ 0\ \ 0\ \ \dots\ \ 0\ \ 0\ \ 0]$$

Similarly,

$$psig(P_1, V_{comp}) = [0\ \ 0\ \ \boldsymbol{p_1}\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ \dots\ \ 0\ \ 0\ \ 0]$$

$$psig(P_q, V_{comp}) = [0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ 0\ \ \dots\ \ 0\ \ 0\ \ \boldsymbol{p_q}]$$

Then obviously:

$$psig(V_{comp}) = \sum_{k\in\mathbb{S}(V_{comp})} \sum_{i\in\mathbb{p}(V_k)} psig(P_i, V_{comp})$$

Here $\mathbb{S}(V_{comp})$ denotes the set of the indices of all semantic particles which the composite V_{comp} is composed from.

Another way to partition the signature matrix into block matrices is:

$ssig(V_{comp}) = [\boldsymbol{V_1}\ \boldsymbol{A_{1,2}}\ \boldsymbol{V_2}\ \boldsymbol{A_{1,3}}\ \boldsymbol{V_3}\ \dots\ \boldsymbol{A_{6,8}}\ \boldsymbol{V_8}\ \boldsymbol{A_{6,9}}\ \boldsymbol{V_9}]$

The block matrix $\boldsymbol{V_1}$ represents the property tree of the particle V_1 and it is given by:

$\boldsymbol{V_1} = [\boldsymbol{p_0}\ \ \boldsymbol{a_{0,1}}\ \ \boldsymbol{p_1}\ \ \boldsymbol{p_0}\ \ \boldsymbol{a_{0,2}}\ \ \boldsymbol{p_2}\ \ \boldsymbol{p_0}\ \ \boldsymbol{a_{0,3}}\ \ \boldsymbol{p_3}\ \ \dots\ \ \boldsymbol{p_0}\ \ \boldsymbol{a_{0,k}}\ \ \boldsymbol{p_k}]$

The block matrix $\boldsymbol{A_{1,2}}$ describes the connection between the particles V_1 and V_2 connecting the root properties of both as:

$\boldsymbol{A_{1,2}} = [\boldsymbol{p_0}\ \ \boldsymbol{a_{0,k+1}}\ \boldsymbol{p_{k+1}}]$

Here are some interesting properties of $ssig(V_{comp})$:
The number of rows N in $ssig(V_{comp})$ is 3 × the number of arcs in the augmented property tree of V_{comp}.
The rank of