Particle Approach for creating Physics-based Semantic Algorithms

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Types of particles

V-particle: *semantic particle* or *node particle* – smallest unit of semantic information. Represent the nodes in the DAG of a semantic structure.
N-particle: *naked particle* - special kind of V-particle which contains only single property – $text$ and is connected to other naked particles through A-particles.
A-particle: *connection particle* or *association particle*, carrier of the attraction force between two (possibly naked) V-particles. Represents the arcs in the DAG of a semantic structure.
P-particle: property particle, carrier of the properties of the V-particles

M-particle: *mass particle* – carrier of the mass of a V-particle or a semantic structure
Q-particle: *charge particle* carries the charge of a V-particle which determines if a pair of V-particles will repel or attract each other and by what "force".

R-particle: *rank particle* - used to determine the relative order of a structure
T-particle: *time particle* – contains a time marker which is a measure of the longevity of a given semantic particle. As soon as T-particle attaches to a semantic particle it cannot be split or decay for the lifespan of that semantic particle that is until that semantic particle splits or decay.

E-particle: *execution particle* – executes an operation when attached to a V-particle
D-particles: *director particle* – a special type of E-particle. Directs the execution to the attached to it E-particles. Serves as a switch which routes the execution to the relevant execution tree branch.

Laws governing the creation, merging, splitting and decay of particles

Laws of repulsion and attraction
Particles with opposite charges attract each other. Particles with the same charge sign repel each other.

Particle eviction with replacement: it occurs when a particle with similar enough signature to the one being evicted is found in an outer context if the first is attracted stronger to the nearby particles than the one which is being evicted.

Particle eviction without replacement: it occurs when a charge of a particle is altered such that the "force" binding the particle to its neighbors changes sign from attractive to replacement.

The idea is to maximize the attraction force in a semantic structure through binding and eviction of particles to it. We should be guided by the structural charges and generated forces. A set of particles with total charge close enough to zero becomes an *independent thought*.

Example:
John is the father of Sam. Julie is the mother of Sam. If a person is your father and another person is your mother then you are their son.

V-particles are rearranged together with A-particles into a DAG via the laws of repulsion and attraction

Conservation laws
Are such laws applicable in Semantic space and if yes under what settings?
Conservation of mass
Conservation of charge
Conservation of color
Conservation of energy
Conservation of momentum

Process for transforming raw particles into semantic structure

The purpose of this process is to associate already existing semantic particles with each raw particle in a set of raw particles. This association process may require splitting and merging raw particles from the set into another set of raw particles. The algorithm by which we transform the original raw particles through splitting and merging into a new set will be discussed in this Section.

N
|
MR_1---------$text$-------MR_l
/ | \
/ | \
MA_1 MA_2 … MA_k
/ | \
AS_1 AS_2 … AS_k
| | |
MA^1 MA^2 … MA^k
| | |
$text_1$ $text_2$ … $text_k$
| | |
V_1 V_2 … V_k

MA – match-seeking particle
MR – match-repelling particle – acts as a repellent toward particular association particles. Models constraints imposed on certain V-particles in terms of similarity matching
AS – similarity particle: a special type of link particle (A-particle)
N – naked particle candidate for dressing
$text$ – the text property value of the naked particle N
V_i – V-particle (semantic particle)

Match-seeker particle

Match-seeker particle is denoted with MA aka MA-particle. We do not usually depict this kind of particles in our graph representations.
Attaches to a specific property with specific prop-name and prop-value. The property value is a vector which is a key allowing the match-seeker particle to be attached to this property. The match-seeker particle exposes a pattern serving as an attraction of an association link particle which would recognize

the pattern and attach to the match-seeker. Each match-seeker particle has a property *`charge`* (type *`default`*) with a value indicating the strength of the charge.

$$MA(key\_pattern, pvalue) - V(pvalue)$$
|
$$A(key\_pattern, key\_pattern2) \text{———————} MA(key\_pattern2, pvalue2) - V_{other}(pvalue2)$$

Match Repelling particle

Repelling particle is denoted with MR aka MR-particle. We do not usually depict this kind of particles in our graph representations.
Attaches to a specific property with prop-value, a vector allowing a repelling particle to be attached to this property. The repelling particle exposes a pattern serving to repel an *association-link* particle which has a property matching the pattern. Each repelling particle has a property *`charge`* (type *`float`*) with a value indicating the strength of the charge.

To each property of object particle V can be attached multiple MA-particles and MR-particles.

Coulomb's law for semantic particles

Let the particle V_{p_1} has "charge" with value q_1 and particle V_{p_2} has property "charge" with value q_2. Then if $sign(q_1) \neq sign(q_2)$ there will be attraction force between the two particles with magnitude F:

$F(V_{p_1}, V_{p_2}) = K \times \frac{|q_1| \cdot |q_2|}{f(r)}$ where $K > 0$ is some proportionality constant and
$f(r)$ is some monotonously increasing function of the semantic distance $r\left(V_{p_1}, V_{p_2}\right)$ between the two particles. If $sign(q_1) = sign(q_2)$ the force would be repelling and will be with the same magnitude F.

<u>Questions which we need answers for :</u>

1) When do we split the raw particle N into a set of new raw particles N1, N2, …, Nl ?
2) When can we establish viable association link between a pair of particles from a set?

Consider a set of k V-particles semantically close to each other: $V_1, V_2, \dots, V_k$
Let us assume that we have established a viable association between a pair from the set:

$\exists\ i, j \in [1, \dots, k]$ V_i --- MA_i --- AS_i --- MA^j --- V_j

Let us assume we have a set of pairs for which association link can be established:

$(i_1, j_1), (i_2, j_2), \dots, (i_l, j_l),\ l = 1..k^2$

Let us consider the first matched tuple (i_1, j_1)

N

|

$text$

/ \

MA_{i_1} MA_{j_1}

/ \

/ \

/ \

/ \

AS_{i_1} AS_{j_1}

/ \

/ \

/ Loop \

/ L_{i_1,j_1} \

MA^{i_1} MA^{j_1}

/ \

$text_{i_1}$ $text_{j_1}$

/ \

V_{i_1} -–- $MA_{(V_{i_1})}$—$AS_{(i_1,j_1)}$—-$MA_{(V_{j_1})}$—- V_{j_1}

The loop N-MA_{i_1}-AS_{i_1}-MA^{j_1}-V_{i_1}-$MA_{(V_{i_1})}$-$AS_{(i_1,j_1)}$-$MA_{(V_{j_1})}$-V_{j_1}-MA^{j_1}- AS_{j_1}-MA_{j_1}- N will be denoted with L_{i_1,j_1}.

The binding force F^b of the association loop L_{i_1,j_1} is given with:

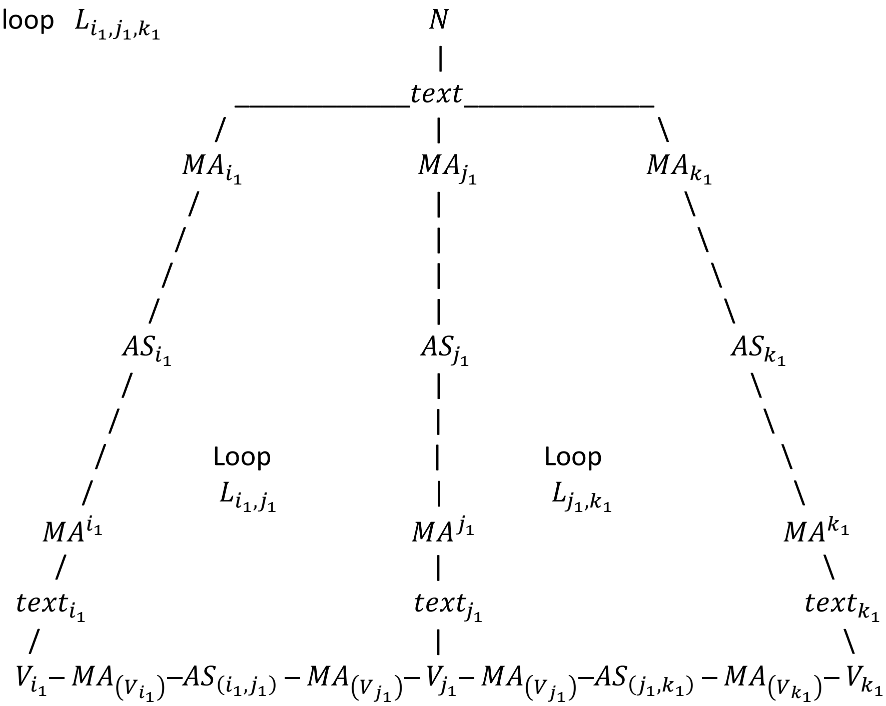
$$F^b\left(L_{i_1,j_1}\right) = F\left(MA_{i_1}, AS_{i_1}\right) + F\left(MA^{i_1}, AS_{i_1}\right) + F\left(MA_{(V_{i_1})}, AS_{(i_1,j_1)}\right) + F\left(MA_{(V_{j_1})}, AS_{(i_1,j_1)}\right) + F\left(MA_{j_1}, AS_{j_1}\right) + F\left(MA^{j_1}, AS_{j_1}\right)$$

Here the attraction force $F\left(MA_{i_1}, AS_{i_1}\right)$ between the match seeing particle MA and the similarity particle AS is given with the Coulomb's law for semantic particles.

To each pair (i_1, j_1), (i_2, j_2), … , (i_l, j_l) for which an association loop can be established we can compute the binding force $F^b\left(L_{i_1,j_1}\right)$, $F^b\left(L_{i_2,j_2}\right)$, …, $F^b\left(L_{i_l,j_l}\right)$

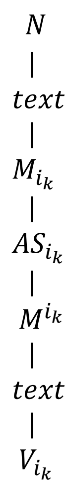
Note that we are not going to consider higher order loops like the one below. It will become clear later in the discussion on the recursive application of this procedure that those higher order loops are redundant.

Higher order loop L_{i_1,j_1,k_1}



Notice that $L_{i_1,j_1,k_1} = L_{i_1,j_1} \cup L_{j_1,k_1}$
Similarly, we can define higher order loops by merging lower order ones:
$L_{i_1,j_1,k_1,\dots,q_1} = L_{i_1,j_1} \cup L_{j_1,k_1} \cup \dots \cup L_{p_1,q_1}$

Besides loops we can have association chains hanging from N. The binding force for the association chain C_{i_l} of N is expressed as:
$F^b(C_{i_1}) = F(MA_{i_1}, AS_{i_1}) + F(MA^{i_1}, AS_{i_1})$



On the Figure on the left: association chain C_{i_l} for raw particle N

Let us denote by $\mathfrak{F}^b$ the set of the binding forces for possible association loops and chains:
$\mathfrak{F}^b = \{F^b(L_{i_1,j_1}), F^b(L_{i_2,j_2}), \dots, F^b(L_{i_l,j_l}), F^b(C_{i_1}), F^b(C_{i_2}), \dots, F^b(C_{i_m})\}$

Let $F^b_{max} = max(\mathfrak{F}^b)$. If F^b_{max} is the binding force of an association loop then the raw particle N will be split into two sub-particles N_1 and N_2.