

## The Notion of Semantic Simulation

D. Gueorguiev 2/11/2023

I am personally interested in LLMs and the problem of modeling human-like reasoning in general. Related to this is my interest in tackling in a coherent way the problem of modeling of semantic inferences. Specifically, I am looking into a semantic inference model based on semantic structures governed by equations of evolution. Let me expound on the latter. I believe that in order to model human-like reasoning we need to pose the problem of extracting semantic meaning and generating semantic inferences in a different way than the existing methods adopted in LLMs. That is – we will define a *semantic simulation* as a process in which appropriately defined laws are governing the evolution through time of semantic structures populating the *semantic space* (or *simulation space*). Here *semantic space* is defined as a metric space with  $N$  dimensions. The chosen metric in that space is *the semantic distance*. Let us assume that this semantic environment accepts textual input which is partitioned into *text quanta*. A *text quantum* represents a portion of the textual information with inherent semantic meaning. Each new set of quanta introduced to the environment will result in creating a new *semantic structure* in the metric space. Think of this structure as a collection of *semantic particles* in this space. This collection of particles evolves using some laws of attraction and conservation of certain quantities defined in that metric space. Each semantic particle has intrinsic properties which characterize it. One intrinsic property to every semantic particle is its *semantic mass*. Another intrinsic property to each semantic particle is its *semantic energy*. The propensity of semantic structures and particles to combine together in larger semantic structures is modeled via *semantic attractive / repulsive forces*. Introducing new structures (corresponding to new textual input in the environment) in this space will alter the position, the movement and the composition of the existing structures. The distance (the metric) between two structures in that space will correspond to their semantic similarity. The closer semantically are two structures the smaller the distance between their centers.

Reinforcement learning in this environment is implemented via the mediation of particle properties such the semantic energy of the particle. Specifically, the acquired semantic energy of a semantic particle depends on its past trajectory and past trajectories of other particles. In turn the current position and the future movement of the semantic particle will depend on its semantic mass and acquired semantic energy.

Inference in that space is done by recognizing patterns in the created structures and their trajectories. Matching the recognized patterns will lead to creating new structures. The inherent semantic properties of the newly created (inferred) structures will determine the motion and trajectories which in turn will influence the existing semantic structures. Hence semantic inference will alter the semantic distances and composition of the structures in proximity of the newly inferred structures. Thus, Semantic Inference will alter the semantic meaning assigned to the points in the region of interest.

For the purpose of understanding and modeling Semantic Inference it is defined a new construct *Semantic Template*. Each Semantic Template is a composite structure which exists in a different than Semantic Space metric space which will be denoted as *Template Space*. Each *Semantic Template* is composed of two pieces – *Pattern Matching Structure* and *Inference Structure*. The *Pattern Matching Structure* is bound to specific region of *Semantic Space* which it tracks for certain patterns. The patterns of interest are the presence of certain semantic signatures with certain trajectories. As soon as it detects a pattern which it is tuned to recognize the *Pattern Matching Structure* notifies the *Inference Structure* of the same template. In result, the *Inference Structure* produces a *Inferred Semantic Structure* in specific place and time in *Semantic Space*. In effect the *Inference Structure* is also bound to a region in *Semantic Space* in which it creates the newly inferred structure. Thus, we say that the *Semantic Template* has been *triggered* and has *produced an inference*.

Further study on Semantic Templates and their desired properties is required. However, certain desired properties and behavior of the Semantic Templates are obvious even at this moment.

The semantic templates will behave as a special kind of semantic structures confined to their own region of Template Space. Each semantic template will be bound to a specific region in Semantic Space (not necessarily *simply connected*) which will track for patterns it is tuned to recognize and in which it will create inferences. Each Semantic Template will follow certain equations of evolution in Template Space which will govern its motion and the eventual aggregation with other Semantic Template structures to produce more complex Template Structures. A simple example of Chained Templates is discussed in [the document](#) below. We need to understand the meaning of the metric *distance* in Template Space – what does it mean for two Template Structures to be close to each other in Template Space? Does it mean that regions in Semantic Space they are bound to will be close? Or it means that the kind of patterns they are going to recognize will be somewhat similar? How does the Inference Structures factor in the definition of a distance between two Semantic Templates? So the completion of the Semantic Template concept will depend on finding meaningful answers to these questions.

More details on this simulation environment as well as key definitions and formulations can be found in the links below:

<https://github.com/dimitarpg13/aiconcepts/blob/master/docs/OnTheNeedofDynamicSimulationWhenModelingInteractionsOfSemanticStructures.pdf>

<https://github.com/dimitarpg13/aiconcepts/blob/master/docs/ModelingAttractiveRepulsiveForcesInSemanticProperties.pdf>

<https://github.com/dimitarpg13/aiconcepts/blob/master/docs/ReinforcementMechanismInSemanticStructureModels.pdf>

<https://github.com/dimitarpg13/aiconcepts/blob/master/docs/SemanticTemplates.pdf>

<https://github.com/dimitarpg13/aiconcepts/blob/master/docs/PracticalExamplesUsingSemanticSimulationWithRL.pdf>