The Relation Between Time and Meaning

Giray Songul

Department of Cognitive Science
Middle East Technical University
giray.songul@metu.edu.tr

July, 2019

Abstract

There are at least two strong opinions in computational theories of mind arguing whether the syntax suffices to produce semantics. In this paper, using intuitions from recently developed artificial neural network models, I dive deep into the problem of exactly where semantics are formed in a syntactic system such as a brain. The main argument is that the semantic value is formed only on the presence of time using nonlinear activation functions and its main purpose is to create time efficiency for its possessor.

Introduction

In order to be consistent, we need to define what are syntax and semantics. This is necessary because there are many different definitions which could result in misconceptions as one may go beyond definitions to infer relations between them. Below are the conventional definitions of the both.

The word "syntax" is generally defined as the properties of symbols and relations among them in order for further manipulation. It consists of the elements of the initial set and the structural relation rules among them. For a natural language, the initial set is the lexical units that is formed using an alphabet. These elements are which all interpreters agree on the initial phase of the communication. Then agents use syntactic rules to come up with new utterencas to convey meaning to one another. If there were no agreements between the agents, there would be miscommunication. It is also agreed that the syntax is independent of interpreters.

The word "semantics" on the other hand, is the study of meaning and truth. The meaning of a word might be its referent in the interpreter's mind. The word "apple" corresponds to the mental representation of a real apple for an agent. Here what a word might refer is not limited by reality. A referent might be anything that an agent has experienced with its brain. It could be physical objects where relations are clear or it could be intangible, abstract forms of thought. Here the importance lies on the word group "mind's experience". Starting with the physical reality, a mind could use any experience, say any sequence of neuron firing in neuroscientific terms, as a referent. Moreover, it could also use any of the previous referents to form new referents. Therefore, it has a strong recursive capability. Unlike syntax, semantics is said to be dependent on the interpreter. It is not logical to say that what a word means is independent of agents that interpret.

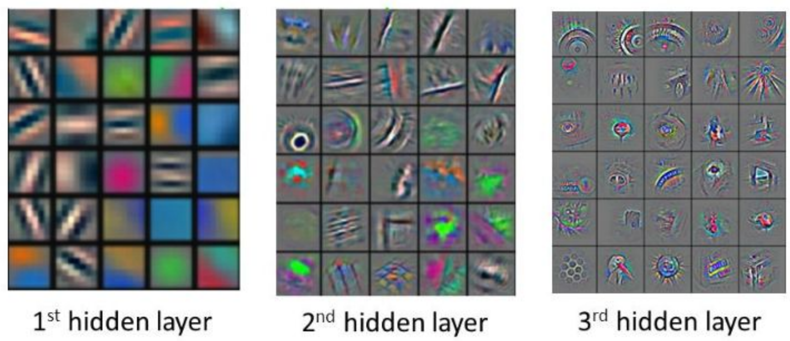
In natural language, when there is no room for further top-to-bottom syntactic analysis, semantic values of the lexical items remain. Therefore, semantic analysis need to be executed in order to understand the deeper relations of communication. However, we know that the human brain is also a syntactic system. Although it is not clear how mind encodes the internal representations, we have gained a great knowledge about its unit structure, a neuron. As far as we know, a neuron operates with the help of its axon, cell body and dendrites. If a neuron receives enough signal that exceeds a certain threshold, it becomes active and outputs a signal through its axon to its neighbouring neurons. We know that the mind of a person have about 80-100 billion neurons that each has 100-1000 connections by its neighbouring cells. Mathematical models also show that combinations of neurons also have a syntactic model and could be solved by formal languages [McCulloch and Pitts, 1943]. Therefore, all operations of the mind including memory are in the hands of this huge neural network. In the light of biological facts, nothing prevents us to argue that whether it is all about syntactic operations which realizes the semantics. After all, this is the system lying underground. However, the relation between this syntactic system and how it creates semantics is still a mystery. In this paper, starting from the inuitions from recently developed artificial neural network models, we will try to fill this gap.

Intuition from Artificial Neural Networks

After the symbolic systems that tries to replicate mind on higher level representations, a bottom-up approach which tries to mathematically model architectures that has artificial neurons have created connectionist networks. Recently, great achievements have been recorded on the field of deep learning which uses deep layers of these neurons. In many fields from computer vision to healthcare, many models have already surpassed the human-level accuracy on different tasks. Although one can argue that these models are not good representations of the human mind [], achieving tasks such as recognizing complex objects, voices or even context were considered to be beyond computation capabilities of computers in the past. Therefore, we need intuitions from recent developments about how these networks might understand the inputs given and whether the underlying operation could help us to reveal what is actually going on inside a real mind.

A simple working mechanism of a deep artificial neural network, although consists of complex mathematical operations, is quite simple. A basic model consists of layers that has neurons which have weighted connections to other neurons. Architecture of the connections might change according to different proposed models, however the main working mechanism is the same. Starting with random weights, a supervised model computes its output according to the given data and its initial weights. A cost function is used to calculate the error of the result compared to the real labeled data. Afterwards, this error is propagated back through the network and updates the weights of connections between neurons. If the architecture and hyperparameters of the network is well chosen and the input data is a good representation of the problem that it tries to solve, the model generalizes the input data so well that it can make very accurate predictions on new unseen data.

Deep learning models are considered to be black box models. This is due to the process of end to end learning and it is hard to understand how each layer and each neuron is contributing to the end prediction. However, some techniques are developed in recent years that tries to understand the contributions of each layer and its neurons []. Using these techniques, we see that the neurons on the very first layer of a CNN model for a computer vision task, activate on simple visual patterns such as lines or brief color changes. Second layer neurons are using the activations from the previous layer and they activate on a little more complex visual patterns such as edges, circles, parallel lines etc. Third layer is also doing the same and it uses the previous layer activations to capture more complex patterns. This process goes through the network and complexity of the pattern increases as we go deeper in terms of layers. Finally, the model captures the desired output such as a cat or a human face.



Reference: Zeiler, M. D., & Fergus, R. (2014). Visualizing and understanding convolutional networks. In *Computer Vision–ECCV 2014* (pp. 818-833)

The main question in a deep neural network is whether the semantic value increases as we go deeper throughout the network. Starting from the raw input, the model uses syntactic operations to form an output which tells us if the given input is meaningful in terms of the desired class, checking the truth value of the statement that the given input is equal to the desired output. Hence, we can say that the end result possesses semantic value for humans. Additionally, this semantic value is increasing as it accumulates throughout the layers in the network. Therefore, it is quantitative.

Here, a question might arise. Is there a correlation between the complexity of the pattern and its semantic value? There are deep learning models that are trained on random noise, and these unsupervised models learn patterns from them []. Do the learned patterns possess meaning? The first intuition is that they do not. This indicates the mind dependency of the meaning. We assign meaning to classes only if they have a representation about the environment, or as we said in the definition of the semantics, mind's experience. Therefore, a noise pattern is not useful for an agent in the outer world directly with the condition that it does not play a role to form a higher semantic value for another pattern. It would probably be very useful in a theoretical scenario in which the agent lives in an environment full of noise. Dynamics of how semantic value propagates is a hard subject to explore because of the fact that it is hard to value the usefulness of patterns in outer world. This is why I leave this subject here and go further on the journey about the fundamentals about exactly where and how the semantic value starts to be formed.

Pursuit of Semantic Unit

A. Going Shallow on a Deep Neural Network

If meaning is quantitative, there should be a semantic unit. If the meaning is accumulated through going deeper through a deep neural network, it should also decrease as going shallower. The first contribution to semantic value is then created on the very first layer of the network which have direct contact with the raw input. Meaning is started to be formed with the operation of a basic neuron. However, the incremental contribution of this first neuron is probably not comprehensible for us. Here we need to investigate further to find where exactly the semantic value starts to be created in a neuron's operation. We need to look closer to the dynamics of neurons.

As indicated in the introduction, if a neuron receives enough signal that exceeds a certain threshold, it becomes active and outputs a signal through its axon to its neighbouring neurons. This operation is a conditional operation in the basic sense. This conditional phenomenon is modeled with activation functions in artificial neural networks. There are several activation functions used in deep learning such as sigmoid, relu, tanh etc. However, in order to capture complex representations in a deep network, activation functions need to be nonlinear. It is mathematically shown that using linear activation functions in a deep network destroys the benefit of using many layers []. In such a case, the same network can be modeled as a one layer network. Therefore, we can say that the nonlinearity of the activation functions has a crucial importance for the whole system to work.

We can see the same phenomenon in transistors as well, the processing unit of any computer today. For example, a BJT (bipolar junction transistor) has three arms: base, collector and emitter. Enough current in the base opens the transistor and a large current between the collector and emitter occurs. Here, again, there is a threshold for the base current, a conditional control structure just like neurons. The only difference of modeled neurons is that there can be more than one input to a neuron. Weighted sum of the inputs is then compared against the threshold. Therefore fundamentally, the main control structure of transistors and neurons are the same.

C. Philosophy of Nonlinear Activation Functions

After seeing the importance of nonlinear activation functions on semantics generating systems, we need to look further into why and how a nonlinear activation function starts to create meaning. Nonlinear activation functions is nothing but conditional statements in the basic sense. Here nonlinearity provides to create conditional statements that the condition and the result are linearly independent. This phenomenon is the basis of association in any mind. It provides the system to associate independent representations.

We can also create an analogy of nonlinear activation functions with if statements, which are the building blocks of any scripting programming language. To understand where and when semantic value is created in an if statement, the purpose of using an if statement should be investigated. There are two main purpose of an if condition that state if A then B:

1. To understand the truth value of B via checking the truth value of A, without checking B explicitly.
2. To execute B in the case that it is a function, only when the value of A is true.

At first sight, the intuition behind the two usages seem like that the first usage is to conceive and the second usage is to execute just like any living organism interact with the real world. We need to conceive the environment around us and act accordingly. However, when looked upon closer, we can see that the two usages are fundamentally the same. For the usage 1, we said that it is used to understand the truth value of B. In order to understand, we need to assign a truth value to it, which is simply a function execution just like the usage 2 either within the programming language or in the brain via neuron states. The only difference comes from the environment in which that function is realized. In order to conceive, we need to change the state of the neurons and in order to execute motor actions, we make a change in the outer world which is again tied to changing the state of neurons that control the action. However, merging two use cases into one makes the intuitions a lot harder to grasp.

D. Time

The later question on the pursuit of semantic value creation could be about why do we use if conditions. What options do we have in a world without if conditions? The answer is quite obvious, we go and check the truth value of B explicitly (For the usage 2 case, without checking the truth value of A, we go and execute the function forever). So what is the gain of using an if condition instead of checking B explicitly? It is time. We gain time by estimating the truth value of B only by checking the truth value of A. The more if conditions we use, the more time efficiency we create. So this must be the answer to the question "where" and "when" semantic value is created. Semantic value can only be created in the presence of time.

This phenomenon could also be related to the time dependency of mind. Mind is a machine to observe inputs and decide on later actions. Hence, there is a direct time dependency. It is not a surprise that the semantic unit of mind is executing a time dependent operation. After all, the main purpose of evolution is to survive and the definition of the word "survive" is to continue to live or exist in the future, and future means the further points on the time domain. Therefore, mind is evolved to create time efficiency for the body and the byproducts of this operation is the meaning.

We can see the time dependency in any sign, which forms the foundation of any language. A sign is an object, quality, or event whose presence or occurrence indicates the probable presence or occurrence of something else. This simple relation between a referee and referent could be formed as an if statement and it is also time dependent. Without the real experience of referent, its sign activates the same mental representation with less time.

Couldn't there be any conditional statements that does not depend on time? Although not obvious, all conditional statements require time's presence because of the time dependency of the mind and especially attention. For example, the relation between numbers on the x axis can be represented with if statements. We could think that there is no time dependency. However, the mind who realizes the if condition can not conceive the x-axis at once, it needs go step by step. This is why even if it seems like time independent, at the end, all conditional statements are time and mind dependent.

The Implications of Time-Meaning Relation

In order to create a time efficiency, mind needs to be faster than the body. Here body represents the survival actions of the agent. Indeed, this is the actual case. Neurons use electrical signals which is much more faster than the actions of the body (E.g. speed of a muscle). In a virtual scenario where mind operates at the same speed or slower compared to the body, it can not create time efficiency , hence there can be no semantic value. It can be said that only a faster system could create semantic value for a slower system.

Time is not absolute, it is relative [], which needs to be taken into account. Faster mind-like systems can create semantic value for relatively slower systems. This phenomenon also indicates that the meaning is also relative. So how come the humans mostly agree on the same semantic values of the words? For example, the semantic value for the “go” is almost identical for humans that understands English. If the meaning is relative, this phenomenon can only be explained via the speeds of mind and body. All humans have the same dynamics operating in their mind and body. This is why the relative meanings are about the same. This is why humans can communicate via language because they live in the same relative meaning domain. In a virtual scenario in which another living organism with a different speed of mind or body would live in a different relative meaning domain. Therefore, communication between this imaginary living organism and humans would be impossible.

What about the agent livings in different time speeds but in the same relative meaning domain? For example, two different people with different speeds. According to Albert Einstein, as the speed increases, time slows down []. This means that the time is slower for the person with the higher speed. Since we have said that meaning is relative between mind and body, we can say that the semantic value created by the two minds are the same. They can communicate however there can be practical problems due to varying speeds.

What if one of the agents gets closer to the speed of light? This is where semantic value starts to diminish. We have said that the main purpose of an if statement is to understand the truth value of B via checking the truth value of A, without checking B explicitly. When agent’s speed is close to the speed of light and time is being close to being zero, physically this means that the agent is anywhere. Hence, relative speed between body and the mind becomes zero. There is no time difference for the agent between checking the truth value of B explicitly and checking it via the truth value of A. When the time stops, meaning stops as well.

References

[McCulloch and Pitts, 1943] McCulloch and Pitts, 1943. A Logical Calculus of the Ideas Immanent in Nervous Activity.

...