**Temporal Memory vs Temporal Pooler vs Spatial Pooler.**

**Feixudong** [feixudong at huawei.com](mailto:nupic-theory%40lists.numenta.org?Subject=Re%3A%20Temporal%20Memory%20vs%20Temporal%20Pooler%20vs%20Spatial%20Pooler.&In-Reply-To=%3CD651520E5BE06C4FA51E8616E5431D4F8FDA780F%40szxeml555-mbs.china.huawei.com%3E)   
*Tue Nov 18 19:12:55 EST 2014*

* Previous message: [Temporal Memory vs Temporal Pooler vs Spatial Pooler.](http://lists.numenta.org/pipermail/nupic-theory_lists.numenta.org/2014-November/001685.html)
* Next message: [Temporal Pooler](http://lists.numenta.org/pipermail/nupic-theory_lists.numenta.org/2014-November/001689.html)
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Hi, Dennis

I might didn’t follow the implementation details, but I understand something wrong in the relationship between low level to high level ( regarding TP ).

Take example of the sequence “ABACADAE”, I understand current CLA treat it as: “ ABA’CA”DA’”E “, renaming the symbol “A” based on different context of it.

Save it in different cells in the same column, establish connections to previous symbol.

If this understanding is correct, there is no problem for the sequence prediction, because each of the A’s is different, unless the the sequence exceed the highest order, such as 32 ( if column have 32 cells )

High level was not needed.

The concept of high level regard TP, we can use another example to show why it is needed, Observing the following sequence:

“ThankyouforclarificationTheterminologyisclearnow”

It can be handled by one level, not problem. But didn’t recognize any high level structure of it.

If we recognize S1=Thank, S2=you S3=clarification …

Then in the high level we remember and handle the new sequence of “S1 S2 S3 ..

Abstraction in time domain happened in this case.

That may also related to the thinking of if we can use spatial abstraction ability to do such kind of abstract at time domain, as spatial abstraction methodology is mature and application proved.

But time domain and spatial domain is different, people had be working on it for tens of years.

Xudong.

From: nupic-theory [mailto:[nupic-theory-bounces at lists.numenta.org](http://lists.numenta.org/mailman/listinfo/nupic-theory_lists.numenta.org)] On Behalf Of Dennis S. Sedov

Sent: Wednesday, November 19, 2014 4:59 AM

To: Feixudong

Subject: Re: Temporal Memory vs Temporal Pooler vs Spatial Pooler.

Jeff,

Thank you for clarification. The terminology is clear now.

On the subject of temporal pooling, how many time steps of the lower level are pooled to the higher level? From what I’ve read I have several contradicting ideas about temporal pooling.

On the surface, general algorithm of temporal memory operates on ideas of columns and cells, where columns are activated by feedforward input (of SP or TP) and then the cells get activated depending on their properties (if the cell is in predictive state, if the cell has higher chance of being activated due to the lowered threshold, if the cell has the least amount of segments)

When this concept is observed in the realm of spatial or temporal pooling, spatial pooling is clear: Encoder feeds the columns each time step. The temporal pooler is what I’m struggling with.

1) One idea I’ve formed due to read material and discussions is simply having active cells feed their activations at each time step to the columns of the next layer. If the cell has been predicted and is excited due to prediction it feeds this fact to the next layer. So if encoder has 10 outputs, the input space of the spatial pooler is exactly 10 cells. For the temporal pooler this expands to all the cells in the lower level. If the lower level has 10 columns with 10 cells in each column, the input space to the higher layer’s TP is 100 cells. So the temporal pooler in this version of understanding is exactly like the spatial pooler but over a larger input space (active columns in the lower level). I believe this idea is completely wrong.

2) Second idea is exactly like the 1) with difference that the time step of the next layer is longer, compared with the time step of the layer below. I.e. lower layer does 5 correct predictions, then the 6th prediction fails, 5 predictions are fed to the higher level as a union. So the time step of the higher level = 5 time steps of the lower level. I guess this confusion comes from the concept of pooling over time. I think this is bit closer.

3) Third idea is that the TP is just like the SP. TP input space is all cells of the lower layer. Input bits are OR’ed with previous bits as long as the lower layer is predicting correctly.

t1. Lower Level: 00100100 TP: 00100100

t2. Lower Level: 100100100 TP: 10110100

t3. Lower Level: 010010010 TP: 11111110

The input of the TP is getting denser with each time step resulting in a union of cell states of the lower level. This is a bit closer, but now it is not clear what should I do with all those bits at each time step.

Having said that, it is clear for me that when encoder feeds the spatial pooler of layer, spatial pooler output perfectly translates into the column space. So I do understand which columns are activated -> SP output, which cells are activated -> depends on the current state of the cell.

In temporal pooler those concepts are not so clear for me, especially in the realm of a single time step.

- So the input space of the TP is obviously all cells in the layer below. This is clear. Cell activated due to prediction is 1, other cells are 0.

- Computation of how the input space becomes the output space (columns) in one time step is not clear.

- The output of the TP is column activation (same as SP). Activate columns, look for predicted cells etc..

Sincerely,

Dennis S. Sedov

On Nov 18, 2014, at 9:37 AM, Jeff Hawkins <[jhawkins at numenta.com](http://lists.numenta.org/mailman/listinfo/nupic-theory_lists.numenta.org)<mailto:[jhawkins at numenta.com](http://lists.numenta.org/mailman/listinfo/nupic-theory_lists.numenta.org)>> wrote:

Dennis,

Yes, we changed some of the naming from what is in the HTM whitepaper. If you look you will find discussions on this naming topic in past email conversations. Your understanding is basically correct. Maybe a few comments will help clarify.

“Pooling” is the mapping of a set of input patterns onto a single output pattern. There are two basic forms of pooling.

“Spatial Pooling” maps two or more patterns together based on bit overlap. If two patterns share sufficient number of bits they are mapped onto a common output pattern.

“Temporal Pooling” maps two or more patterns together based on temporal proximity. If two patterns occur adjacent in time they are likely to have a common cause in the world.

Spatial Pooling can map a huge number of patterns together and it is relatively easy for neurons to do. However, it is limited to pooling patterns that are essentially the same except for noise.

Temporal pooling is more powerful but it is expensive in both learning time and memory required.

Simplistically, the cortex alternates SP and TP over and over again in a hierarchy to build invariant representations.

We believe that SP and TP is occurring in every layer of cells, not just between regions. So SP and TP occur in Layer 4 then Layer 3 then Layer 4 in next region etc.

“Temporal Memory” refers to how a layer of cells in a region learns sequences. Temporal Memory in Layer 3 is a pure high order sequence memory. The same TM mechanism in Layer 4 builds a predictive model of sensory motor sequences. TM in Layer 5 plays back motor sequences. We only do Temporal Pooling if the previous layer of cells correctly predicted input changes using its temporal memory.

Jeff

From: nupic-theory [mailto:[nupic-theory-bounces at lists.numenta.org](http://lists.numenta.org/mailman/listinfo/nupic-theory_lists.numenta.org)] On Behalf Of Dennis S.

Sent: Saturday, November 15, 2014 2:59 PM

To: Jeff Hawkins

Subject: Temporal Memory vs Temporal Pooler vs Spatial Pooler.

I’ve been going through various Wiki’s, discussions and white papers today and found myself a little confused with the difference between Temporal Memory and Temporal Pooler and Spatial Pooler.

Here is my understanding of it:

Temporal Memory is what is described as temporal pooler in the white paper. Algorithm that allows memorizing sequences in a region. Or is it the state of the region after memorization has happened?

Temporal Pooler is an algorithm that is used when hierarchies are involved. I.e. higher region would pool signals as long as the predictions of the lower level are correct. Once they are pooled, higher level creates and SDR from it. But if it creates an SDR, it should have been called a Spatial Pooler, because it pools from a lower level over time, but creates one spatial representation. Perhaps a Temporal Pooler is an algorithm that compresses many SDR’s over time into one SDR…

I would really appreciate clarification. The reason I’ve got confused is the concept of “pooling” is very clear. You gather something over time into a single “pool”. When temporal memory is called temporal pooler - I get confused. It looks like that there has been some naming changes for the past years of Nupic development, so reading old papers and new discussions created this confusion for me, but I would love to have a brief clarification on the subject. Thank you!

With Best Regards,

Dennis S

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