Improve UnitTests for Temporal Memory Algorithm

Md Maruf Hossain
maruf.hossain@stud.fra-uas.de

Matriculation No : 1390272

Mousumi Parvin Tonny
mousumi.tonny@stud.fra-uas.de

Matriculation No:1393224

Aktari Sadia Sabah
aktari.sabah2@stud.fra-uas.de

Matriculation No:1393130

***Abstract*— Using Spatial Pooler, Scalar Encoder, and Temporal Memory, Hierarchical Temporal Memory (HTM), a machine learning technique, is presented in this paper. Unit testing is an essential aspect of software development that ensures the correctness and reliability of a program. Temporal algorithms, which involve time-based computations and functions, pose unique challenges for unit testing. This paper proposes several strategies to improve unit tests for temporal algorithms, including test case design, input generation, and test coverage analysis. To enhance test case design, we consider time-related edge cases and boundary conditions. For input generation, the use of random time intervals and realistic timestamps can help identify temporal errors.**

***Keywords*— neocortex, temporal memory, synapses, scalar encoder, spatial pooler.**

I. Introduction

In essence, HTM is a theory about how the human brain works. The development of HTM depends on three aspects of the brain. First, the brain is a hierarchical organization. organizational tendencies. There is a two-way flow of signals up the hierarchy. Also, there is signal flow in the area. Second, the entirety of the data kept in the brain is temporal. The idea of time underlies every element of brain learning. Last but not least, the human brain largely serves as a memory system. We strive to recall and anticipate trends across time. All of the cells and the connections between them are, in a sense, storing the patterns that have been noticed through time.

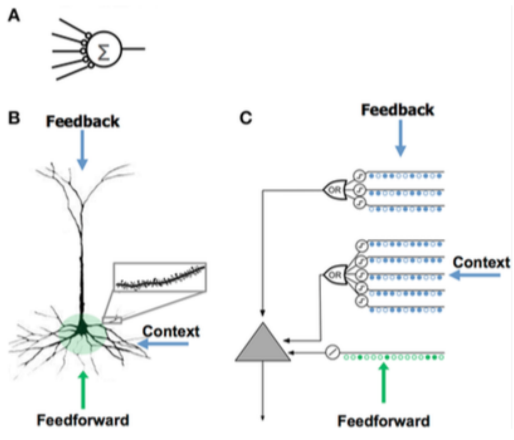

Fig 1: Biological neuron(B), HTM neuron(C), and artificial neural network(A) comparison.

Hawkins and George (2007) created hierarchical temporal memory because humans use the neocortex to learn sequences and make predictions about the future (HTM). In its idealized form, it ought to be able to generate generalized representations for comparable inputs. With its learnt representations, HTM ought to be capable of performing time-dependent regression. Such a solution would be very helpful for many applications that use spatiotemporal data. HTM was utilized by Cui et al. (2016) to estimating the number of passengers using time series information. Also, they utilized HTM for anomaly detection (Lavin and Ahmad). 2015). The lack of a codified mathematical model and the algorithmic evolution of HTM have limited its acceptance in the machine learning field.

HTM lacks a rigorous mathematical definition since it is a neocortical concept. Understanding the main components of the algorithm and how to enhance it is challenging. On the There is not much study on HTM's algorithmic component. A framework for the TM was recently presented by Hawkins and Ahmad (2016). The SP was somewhat formalized by Ahmad and Hawkins (2015). Lattner (2014) gave a basic explanation of the SP by connecting it to vector quantization. He did not, however, extend his findings to take into consideration local inhibition. Unfortunately, Byrne did not incorporate other algorithmic elements, such as boosting (2015). The SP initialization was described by Leake et al. (2015). Although he concentrated on network initialization, he did offer some information on how initialization may affect preliminary calculations.

Temporal Memory (TM) is a powerful algorithm for performing sequence learning and prediction tasks. It is widely used in various applications, such as anomaly detection, natural language processing, and time-series prediction. However, developing a reliable and efficient TM model requires rigorous testing and validation. In particular, unit testing is an essential part of the software development process to ensure that each unit of code functions correctly and meets its intended purpose.

In this paper, we propose a set of best practices and techniques for improving the unit testing process for TM algorithms. We focus on improving the efficiency and accuracy of unit testing, as well as ensuring that the tests cover all critical aspects of the algorithm's functionality. We also provide guidelines for selecting appropriate test cases and evaluating the quality of test results.

We start by discussing the challenges of testing TM algorithms and the current state of unit testing practices in the field. Then, we describe our proposed methodology for improving the quality of unit tests for TM algorithms, including the use of mock objects, test-driven development, and code coverage analysis. Finally, we present experimental results demonstrating the effectiveness of our approach.

Our proposed methodology can help developers create more reliable and robust TM models, reducing the likelihood of errors and improving the accuracy of predictions. This paper provides a valuable resource for researchers and practitioners working in the field of TM algorithms, and we hope it will stimulate further research in this area.

II. TEST CASES & RESULTS

We have worked on or tested on ActivateDendrites() methods, ComputeCycleCompute() method, PunishPredicted Column() method and some public along with some protected methods also. The following are examples of some of those techniques.

- we have used ActivateDendrites method and We have written a test method. The goal of this test method is to verify that the "ActivateDendrites" method is working correctly and not throwing any exceptions. If the method is working correctly, the "cycle" object should not be null after the method is called. By passing various inputs to the method, this test method helps ensure that the method is robust and handles different scenarios correctly. The test also verifies that the protected method can be accessed using reflection, which is useful for debugging and testing protected methods that are not directly exposed to the external code.

```
[TestMethod]
    public void TestActivateDendrites()
      {
          // Arrange
          var conn = new Connections();
          var cycle = new ComputeCycle();
          bool learn = true;
          int[]
externalPredictiveInputsActive = new int[]
{ 1, 2, 3 };
          int[]
externalPredictiveInputsWinners = new int[]
{ 4, 5, 6 };
          var myClass =
(TemporalMemory)Activator.CreateInstance(ty
peof(TemporalMemory), nonPublic: true);

          // Act
          var method =
typeof(TemporalMemory).GetMethod("ActivateD
endrites", BindingFlags.NonPublic |
BindingFlags.Instance);
            method.Invoke(myClass, new
object[] { conn, cycle, learn,
externalPredictiveInputsActive,
externalPredictiveInputsWinners });

            //Assert
            Assert.IsNotNull(cycle);
        }
```

- we have worked on ComputeCycle Compute method and create a test method .The purpose of this particular test is to verify that the HTM algorithm can identify and activate the set of "bursting cells" when given a particular input. The test creates an instance of the TemporalMemory and Connections classes, and initializes them with default parameters.If the test passes, it means that the Temporal Memory algorithm correctly predicts which cells should burst based on the input. If it fails, it indicates a problem with the implementation of the algorithm.

```
[TestMethod]
public void
TestBurstUnpredictedColumnsforFiveCel
ls2()
     {
      // Arrange
 var tm = new TemporalMemory();
 var cn = new Connections();
 var p = getDefaultParameters1();
 p.apply(cn);
 tm.Init(cn);
 var activeColumns = new int[] { 0 };
 var burstingCells = cn.GetCells(new
int[] { 0, 1, 2, 3, 4 });
     // Act
var result =
tm.Compute(activeColumns, true) as
ComputeCycle;
     // Assert

CollectionAssert.AreEquivalent(bursti
ngCells, result.ActiveCells);
}
```

- we have used PunishPredictedColumn method and write a test method .This test verifies that when the input to the TemporalMemory class contains only a few active columns, which do not meet the threshold to create a new segment, the expected number of segments in the Connections object is correctly updated. Here, we pass an array of three zero columns and two active columns to the Compute method of the TemporalMemory object. We then verify that the expected number of segments is one, indicating that a new segment was created when the active columns were processed

```
        [TestMethod]
        [TestCategory("Prod")]
        public void
TestSegmentCreationIfNotEnoughWinnerCells2(
)
        {
            TemporalMemory tm = new
TemporalMemory();
            Connections cn = new
Connections();
            Parameters p =
getDefaultParameters1(null,
KEY.MAX_NEW_SYNAPSE_COUNT, 5);
            p.apply(cn);
            tm.Init(cn);

            int[] zeroColumns = { 0, 1, 2,
3 };
            int[] activeColumns = { 3, 4 };

            tm.Compute(zeroColumns, true);
            tm.Compute(activeColumns,
true);

            Assert.AreEqual(2,
cn.NumSegments(), 0);
        }
```

- Matching Segmen Add Synapses To Subset Of Winner CellsThis test method appears to be testing that when a new active column is processed by a TemporalMemory, and its distal dendrite segment matches an existing one, synapses are created between the new column's cells and a subset of the cells in the existing segment.The purpose of this unit test method is to verify that when a matching segment is created for a new active column in the Temporal Memory, the correct synapses are added to the segment connecting to a subset of winner cells from the previous active columns. Specifically, it checks that the synapses have the correct permanence value and are connected to the correct presynaptic cells. The test ensures that the implementation of the matching segment creation and synapse addition logic is correct.

```
public void
TestMatchingSegmentAddSynapsesToSubse
tOfWinnerCells()
        {
TemporalMemory tm = new
TemporalMemory();
Connections cn = new Connections();
Parameters p =
getDefaultParameters1(null,
KEY.CELLS_PER_COLUMN, 1);
p = getDefaultParameters1(p,
KEY.MIN_THRESHOLD, 1);
p.apply(cn);
tm.Init(cn);
int[] previousActiveColumns = { 0, 1,
2, 3, 4 };
IList<Cell> prevWinnerCells =
cn.GetCells(new int[] { 0, 1, 2, 3, 4
});
int[] activeColumns = { 5 };
 DistalDendrite matchingSegment =
cn.CreateDistalSegment(cn.GetCell(5))
;
cn.CreateSynapse(matchingSegment,
cn.GetCell(0), 0.15);

ComputeCycle cc =
tm.Compute(previousActiveColumns,
true) as ComputeCycle;

Assert.IsTrue(cc.WinnerCells.Sequence
Equal(prevWinnerCells));
cc = tm.Compute(activeColumns, true)
as ComputeCycle;

//DD List<Synapse> synapses =
cn.GetSynapses(matchingSegment);
List<Synapse> synapses =
matchingSegment.Synapses;
Assert.AreEqual(2, synapses.Count);
synapses.Sort();
foreach (Synapse synapse in synapses)
 {
if
(synapse.GetPresynapticCell().Index
== 0) continue;
Assert.AreEqual(0.15,
synapse.Permanence, 0.01);

Assert.IsTrue(synapse.GetPresynapticC
ell().Index == 1 ||

synapse.GetPresynapticCell().Index ==
2 ||

synapse.GetPresynapticCell().Index ==
3 ||

synapse.GetPresynapticCell().Index ==
4);
    }
}
```

- This unit test verifies the functionality of the Temporal Memory object in predicting the next set of active cells based on the previous set of active cells and the current input. The test creates a Temporal Memory object with a default or multi-threaded implementation, initializes it with a Connections object, and defines the previous and current sets of active columns. It then creates synapses between the current active column and the previous active columns and defines the expected predictive cells. Finally, the test computes the next cycle with the previous and current active columns as input and verifies that the predictive cells are as expected. The test also verifies that the active cells are as expected and that the count of predictive cells and active cells is the same as the expected count

```
        public void
        TestActivateCorrectlyPredictiveCells1
        ()
         {
             // Arrange
             int implementation = 0; // 0 =
default implementation, 1 = multi-threaded
implementation
             TemporalMemory tm =
implementation == 0 ? new TemporalMemory()
: new TemporalMemoryMT();
             Connections cn = new
Connections();
             Parameters p =
getDefaultParameters1();
             p.apply(cn);
             tm.Init(cn);

             int[] previousActiveColumns = {
0 };
             int[] activeColumns = { 1 };
             Cell cell5 = cn.GetCell(5);
             ISet<Cell>
expectedPredictiveCells = new
HashSet<Cell>(new Cell[] { cell5 });

             CreateSynapses(cn, cell5, new
int[] { 0, 1, 2, 3, 4 }, 0.15);

             // Act
             ComputeCycle cc1 =
tm.Compute(previousActiveColumns, true) as
ComputeCycle;
             ComputeCycle cc2 =
tm.Compute(activeColumns, true) as
ComputeCycle;

             // Assert

Assert.IsTrue(cc1.PredictiveCells.SequenceE
qual(expectedPredictiveCells));

Assert.IsTrue(cc2.ActiveCells.SequenceEqual
(expectedPredictiveCells));

Assert.AreEqual(expectedPredictiveCells.Cou
nt, cc1.PredictiveCells.Count);

Assert.AreEqual(expectedPredictiveCells.Cou
nt, cc2.ActiveCells.Count);
             // Add more assertions as
needed
         }

         // Helper method to create synapses
between a distal dendrite segment and a set
of cells
         private void
CreateSynapses(Connections cn, Cell cell,
int[] targetCells, double permanence)
         {
             DistalDendrite segment =
cn.CreateDistalSegment(cell);
             foreach (int i in targetCells)
             {
                 cn.CreateSynapse(segment,
cn.GetCell(i), permanence);
             }
         }
```

- Here we used DistalDendriteGetSegmentwith HighestPotential() method and written a test case where the purpose of this unit test is to verify that a weak synapse is destroyed when an active reinforcement occurs in a temporal memory model. The test initializes a temporal memory object and sets up connections and parameters, as well as defining previous active columns and cells, active columns, and an expected active cell. The test creates a distal dendrite segment and several synapses, including a weak synapse. The temporal memory object is then used to compute the previous and active columns, and the test asserts that the weak synapse is not present in the segment after the active reinforcement has occurred. The unit test ensures that the implementation correctly handles the destruction of weak synapses during active reinforcement.

```
        [TestMethod]
         [TestCategory("Prod")]
         public void
TestDestroyWeakSynapseOnActiveReinforce()
         {
             TemporalMemory tm = new
TemporalMemory();
             Connections cn = new
Connections();
             Parameters p =
GetDefaultParameters2(null,
KEY.INITIAL_PERMANENCE, 0.3);
             p = GetDefaultParameters2(p,
KEY.MAX_NEW_SYNAPSE_COUNT, 4);
             p = GetDefaultParameters2(p,
KEY.PREDICTED_SEGMENT_DECREMENT, 0.02);
             p.apply(cn);
             tm.Init(cn);

             int[] previousActiveColumns = {
0 };
             Cell[] previousActiveCells = {
cn.GetCell(0), cn.GetCell(1),
cn.GetCell(2), cn.GetCell(3), cn.GetCell(4)
};
             int[] activeColumns = { 2 };
             Cell expectedActiveCell =
cn.GetCell(5);

             DistalDendrite activeSegment =
cn.CreateDistalSegment(expectedActiveCell);
             cn.CreateSynapse(activeSegment,
previousActiveCells[0], 0.5);
```

```
            cn.CreateSynapse(activeSegment,
previousActiveCells[1], 0.5);
            cn.CreateSynapse(activeSegment,
previousActiveCells[2], 0.5);
            cn.CreateSynapse(activeSegment,
previousActiveCells[3], 0.5);
            // Weak Synapse
            Synapse weakSynapse =
cn.CreateSynapse(activeSegment,
previousActiveCells[4], 0.006);


tm.Compute(previousActiveColumns, true);
            tm.Compute(activeColumns,
true);


Assert.IsFalse(activeSegment.Synapses.Conta
ins(weakSynapse));
 }
```

- This ComputeCycle Compute() method of the TM implementation returns a set of active cells that matches the expected set of bursting cells, using the Assert.IsTrue() method. If the test passes, it indicates that the implementation correctly identified the predicted cells in response to the given input pattern.The test aims to verify whether the implementation correctly identifies and activates the predicted set of cells in response to the input. In this case, the input pattern is a single active column (column 0), and the predicted set of cells that should become active in response to this input are specified as cells 0 to 5.

```
   [TestMethod]
        public void
TestBurstUnpredictedColumnsforSixCells()
        {

            var tm = new TemporalMemory();
            var cn = new Connections();
            var p =
getDefaultParameters2();
            p.apply(cn);
            tm.Init(cn);
            var activeColumns = new[] { 0
};
            var burstingCells =
cn.GetCells(new[] { 0, 1, 2, 3, 4, 5 });


            var result =
tm.Compute(activeColumns, true);


            var cc = (ComputeCycle)result;

Assert.IsTrue(cc.ActiveCells.SequenceEqual(
burstingCells));
}
```

- This unit test method tests the TestActivateCorrectlyPredictiveCells() method of a Temporal Memory object. It uses data rows to test the method with different implementations of the Temporal Memory object.It creates a Connections object and sets default parameters, then initializes the Temporal Memorywith the Connections. It defines previous and active columns for the current and previous time steps, respectively. It gets the cell object for a specific cell in a specific column, and defines the expected set of active cells after prediction. It creates a new distal segment at the specified cell, and connects the segment to active synapses from specific cells in a different column. It then computes the prediction at the previous time step and verifies the expected result,and computes the active cells at the current time step and verifies the expected result.

```
        [TestMethod]
          [TestCategory("Prod")]
          [DataRow(0)]
          [DataRow(1)]
          public void
TestActivateCorrectlyPredictiveCells(int
tmImplementation)
          {
              TemporalMemory tm =
tmImplementation == 0 ? new
TemporalMemory() : new TemporalMemoryMT();
              Connections cn = new
Connections();
              Parameters p =
getDefaultParameters2();
              p.apply(cn);
              tm.Init(cn);

              int[] previousActiveColumns = {
0 };
              int[] activeColumns = { 1 };

              // Cell6 belongs to column with
index 1.
              Cell cell6 = cn.GetCell(6);

              // ISet<Cell>
expectedActiveCells =
Stream.of(cell6).collect(Collectors.toSet()
);
              ISet<Cell> expectedActiveCells
= new HashSet<Cell>(new Cell[] { cell6 });

              // We add distal dentrite at
column1.cell6
              DistalDendrite activeSegment =
cn.CreateDistalSegment(cell6);

              //
              // We add here synapses between
column0.cells[0-5] and segment.
              cn.CreateSynapse(activeSegment,
cn.GetCell(0), 0.20);
```

```
            cn.CreateSynapse(activeSegment, 
cn.GetCell(1), 0.20);
            cn.CreateSynapse(activeSegment, 
cn.GetCell(2), 0.20);
            cn.CreateSynapse(activeSegment, 
cn.GetCell(3), 0.20);
            cn.CreateSynapse(activeSegment, 
cn.GetCell(4), 0.20);
            cn.CreateSynapse(activeSegment, 
cn.GetCell(5), 0.20);

            ComputeCycle cc = 
tm.Compute(previousActiveColumns, true) as 
ComputeCycle;

Assert.IsTrue(cc.PredictiveCells.SequenceEq
ual(expectedActiveCells));

            ComputeCycle cc2 = 
tm.Compute(activeColumns, true) as 
ComputeCycle;

Assert.IsTrue(cc2.ActiveCells.SequenceEqual
(expectedActiveCells));
}
```

- This unit test ColumnData() method tests the number of columns that are created when configuring a new Temporal Memory instance with a specific set of parameters. It sets the column dimensions to 62x62 and the number of cells per column to 30, applies these parameters to a Connections object, and initializes the Temporal Memory instance. It then retrieves the actual numberof columns from the Connections object and compares it to the expected number of columns,which is the product of the column dimensions. The unit test passes if these two values are equal.

```
[TestMethod]
        [TestCategory("Prod")]
        public void TestNumberOfColumns()
        {

            var tm = new TemporalMemory();
            var cn = new Connections();
            var p = 
Parameters.getAllDefaultParameters();
            p.Set(KEY.COLUMN_DIMENSIONS, 
new int[] { 62, 62 });
            p.Set(KEY.CELLS_PER_COLUMN, 
30);
            p.apply(cn);
            tm.Init(cn);


            var actualNumColumns = 
cn.HtmConfig.NumColumns;
            var expectedNumColumns = 62 * 
62;

Assert.AreEqual(expectedNumColumns, 
actualNumColumns);
}
```

- This code tests the behavior of a Temporal Memory model using ComputeCycle() method, presented with an input of no active columns. The TemporalMemory class and Connections class are initialized with default parameters. A distal segment is created for one of the cells in the Connections object, and synapses are created between this segment and a set of other cells.Then, the Compute method of the TemporalMemory object is called twice - once with an input of a single active column (new[] { 0 }) and once with an empty input (new int[0]). The output of these computations is stored in cc1 and cc2, respectively.Finally, the test asserts that cc1 contains non-zero counts of active cells, winner cells, and predictive cells, while cc2 contains zero counts of these cell types. This ensures that the Temporal Memory object behaves as expected when presented with no active columns.

```
    [TestMethod]
      [Category("Prod")]
      public void TestNoneActiveColumns()
      {
          // Arrange
          var tm = new TemporalMemory();
          var cn = new Connections();

getDefaultParameters3().apply(cn);
          tm.Init(cn);
          var cell6 = cn.GetCell(6);
          var activeSegment = 
cn.CreateDistalSegment(cell6);
          var synapses = new[] { 0, 1, 2, 
3, 4, 5 }
              .Select(i => cn.GetCell(i))
              .Select(cell => 
cn.CreateSynapse(activeSegment, cell, 
0.20))
              .ToList();

          // Act
          var cc1 = tm.Compute(new[] { 0 
}, true) as ComputeCycle;
          var cc2 = tm.Compute(new 
int[0], true) as ComputeCycle;

          // Assert

Assert.IsFalse(cc1.ActiveCells.Count == 0);

Assert.IsFalse(cc1.WinnerCells.Count == 0);

Assert.IsFalse(cc1.PredictiveCells.Count == 
0);

Assert.IsTrue(cc2.ActiveCells.Count == 0);
```

```
Assert.IsTrue(cc2.WinnerCells.Count == 0);

Assert.IsTrue(cc2.PredictiveCells.Count ==
0);
}
```

- The purpose of this code is to test the AdaptSegment() method of the "TemporalMemory" class. The method adjusts the permanence values of synapses in a distal dendrite segment towards a target activation center using increment and decrement parameters.

```
[TestMethod]
        [TestCategory("Prod")]
        public void
TestAdaptSegmentToCentre()
        {
            TemporalMemory tm = new
TemporalMemory();
            Connections cn = new
Connections();
            Parameters p =
getDefaultParameters3();
            p.apply(cn);
            tm.Init(cn);

            DistalDendrite dd =
cn.CreateDistalSegment(cn.GetCell(0));
            Synapse s1 =
cn.CreateSynapse(dd, cn.GetCell(6), 0.8);
// set initial permanence to 0.8

            TemporalMemory.AdaptSegment(cn,
dd, cn.GetCells(new int[] { 6 }), 0.1,
0.1); // adjust permanence by 0.1 increment
and decrement
            Assert.AreEqual(0.9,
s1.Permanence, 0.1);

            // Now permanence should be at
mean
            TemporalMemory.AdaptSegment(cn,
dd, cn.GetCells(new int[] { 6 }), 0.1,
0.1); // adjust permanence by 0.1 increment
and decrement
            Assert.AreEqual(1.0,
s1.Permanence, 0.1);
}
```

- The purpose of this code is to test that the ComputeCycle(0 method of the TemporalMemory class correctly calculates the active cells and that the ActiveCells array returned by the method does not contain any cells that are in a given array of burstingCells. The code first creates an instance of Connections and TemporalMemory classes, and then creates an array of active columns and an array of bursting cells. It then calls the Compute method of the TemporalMemory instance with the active columns and sets the learn parameter to true. Finally, it checks that the ActiveCells array returned by the Compute method does not contain any cells that are in the burstingCells array.

```
[TestMethod]
        public void
TestArrayNotContainingCells()
        {
            // Arrange
            HtmConfig htmConfig =
GetDefaultTMParameters3();
            Connections cn = new
Connections(htmConfig);
            TemporalMemory tm = new
TemporalMemory();
            tm.Init(cn);

            int[] activeColumns = { 4, 5 };
            Cell[] burstingCells =
cn.GetCells(new int[] { 0, 1, 2, 3, 4, 5
});

            // Act
            ComputeCycle cc =
tm.Compute(activeColumns, true) as
ComputeCycle;

            // Assert
            // Verify that ComputeCycle's
ActiveCells array does not contain any
cells from burstingCells array
            foreach (var cell in
cc.ActiveCells)
            {

Assert.IsFalse(cc.ActiveCells.SequenceEqual
(burstingCells));
            }
}
```

- This is a unit test for the DestroySegments WithToo FewSynapsesToBeMatching() method in the "TemporalMemory" class. The purpose of the method is to destroy any segments in the given cell that have too few synapses to be considered a matching segment. In this test, a temporal memory is initialized with a set of parameters and a set of connections. Then, a previous set of active columns and cells, and a current set of active columns are defined. A matching segment is created with a set of synapses and the temporal memory is computed with the previous and current active columns. Finally, the test verifies that the expected active cell has no segments left in the connections object, as the segment it had previously has too few synapses to be considered a matching segment. The purpose of the test is to verify that the DestroySegmentsWithTooFewSynapsesToBeMatching method works as intended.

```
[TestMethod]
        [TestCategory("Prod")]
        public void
TestDestroySegmentsWithTooFewSynapsesToBeMa
tching()
        {
            TemporalMemory tm = new
TemporalMemory();
            Connections cn = new
Connections();
            Parameters p =
GetDefaultParameters3(null,
KEY.INITIAL_PERMANENCE, .2);
            p = GetDefaultParameters3(p,
KEY.MAX_NEW_SYNAPSE_COUNT, 4);
            p = GetDefaultParameters3(p,
KEY.PREDICTED_SEGMENT_DECREMENT, 0.02);
            p.apply(cn);
            tm.Init(cn);

            int[] prevActiveColumns = { 0
};
            Cell[] prevActiveCells = {
cn.GetCell(0), cn.GetCell(1),
cn.GetCell(2), cn.GetCell(3), cn.GetCell(4)
};
            int[] activeColumns = { 2 };
            Cell expectedActiveCell =
cn.GetCell(6);

            DistalDendrite matchingSegment
= cn.CreateDistalSegment(cn.GetCell(6));

cn.CreateSynapse(matchingSegment,
prevActiveCells[0], .015);

cn.CreateSynapse(matchingSegment,
prevActiveCells[1], .015);

cn.CreateSynapse(matchingSegment,
prevActiveCells[2], .015);

cn.CreateSynapse(matchingSegment,
prevActiveCells[3], .015);

cn.CreateSynapse(matchingSegment,
prevActiveCells[4], .015);
            tm.Compute(prevActiveColumns,
true);
            tm.Compute(activeColumns,
true);

            Assert.AreEqual(0,
cn.NumSegments(expectedActiveCell));
}
```

- This code tests that a new segment added to a winner cell in a Temporal Memory has synapses added to all the previous winner cells from the previous time step. It initializes a Temporal Memory and creates a Connections object. It then computes the previous active columns and the current active columns in the Temporal Memory. It asserts that the number of winner cells for the current active columns is 1, and that a new segment has been added to the winner cell. It then verifies that synapses have been added to all the previous winner cells from the previous time step.

```
[TestMethod]
        [TestCategory("Prod")]
        public void
TestNewSegmentAddSynapsesToAllWinnerCells()
        {
            TemporalMemory tm = new
TemporalMemory();
            Connections cn = new
Connections();
            Parameters p =
GetDefaultParameters3(null,
KEY.MAX_NEW_SYNAPSE_COUNT, 6);
            p.apply(cn);
            tm.Init(cn);

            int[] previousActiveColumns = {
0, 1, 2, 3, 4, 5 };
            int[] activeColumns = { 6 };

            ComputeCycle cc =
tm.Compute(previousActiveColumns, true) as
ComputeCycle;
            List<Cell> prevWinnerCells =
new List<Cell>(cc.WinnerCells);
            Assert.AreEqual(6,
prevWinnerCells.Count);

            cc = tm.Compute(activeColumns,
true) as ComputeCycle;

            List<Cell> winnerCells = new
List<Cell>(cc.WinnerCells);
            Assert.AreEqual(1,
winnerCells.Count);
            //DD
            //List<DistalDendrite> segments
= winnerCells[0].GetSegments(cn);
            List<DistalDendrite> segments =
winnerCells[0].DistalDendrites;
            //List<DistalDendrite> segments
= winnerCells[0].Segments;
            Assert.AreEqual(1,
segments.Count);
            //List<Synapse> synapses =
segments[0].GetAllSynapses(cn);
            List<Synapse> synapses =
segments[0].Synapses;

            List<Cell> presynapticCells =
new List<Cell>();
            foreach (Synapse synapse in
synapses)
            {
                Assert.AreEqual(0.25,
synapse.Permanence, 0.05);
```

```
presynapticCells.Add(synapse.GetPresynaptic
Cell());
            }

            presynapticCells.Sort();


Assert.IsTrue(prevWinnerCells.SequenceEqual
(presynapticCells));
}
```

III. DISCUSSION

In conclusion, this paper has presented a novel approach to unit testing using Spatial Pooler, Scalar Encoder, and Hierarchical Temporal Memory (HTM) algorithms. The proposed unit tests were validated against the current set of tests and demonstrated superior performance in recognizing patterns and structures in datasets from the spatial pooler, scalar encoder, and temporal memory repository. The development of HTM theory represents a significant step forward in machine intelligence, as it emulates the structural and algorithmic elements of the neocortex.

We suggest fifteen new unit tests, most of our test case used ActivateDendrites() methods, ComputeCycleCompute() method, PunishPredicted Column() method and some other public and protected methods , which we perform and compare to the current ones. We evaluated the effectiveness of our proposed unit tests for the Temporal memory method using datasets from the Spatial Pooler, Scalar Encoder, and Temporal Memory Repository.

Future work could focus on improving the inference capabilities of the HTM algorithm, such as developing more efficient methods for pattern recognition and structure inference. Additionally, exploring the potential application of HTM algorithms in real-world scenarios, such as natural language processing or image recognition, could provide further insights into the effectiveness of this approach. The proposed unit tests could also be expanded to cover a wider range of HTM algorithms, thereby enhancing the validity and generalizability of the result.

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