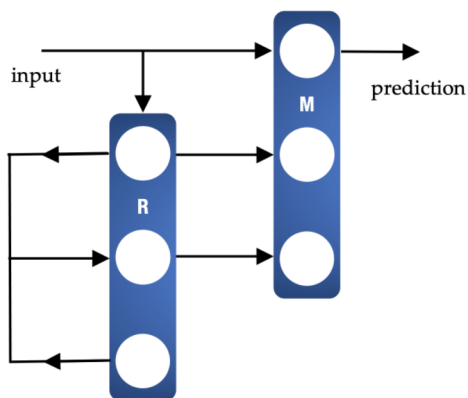


## Deep Temporal Memory - Introduction

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### Algorithm

A simple temporal memory algorithm can be composed of two triadic memory instances, wired together in the following circuit:



In this circuit, triadic memory R creates a random context vector for a consecutive pair of inputs, and feeds it back to the delayed input. This element effectively creates context-dependent bigrams from consecutive inputs.

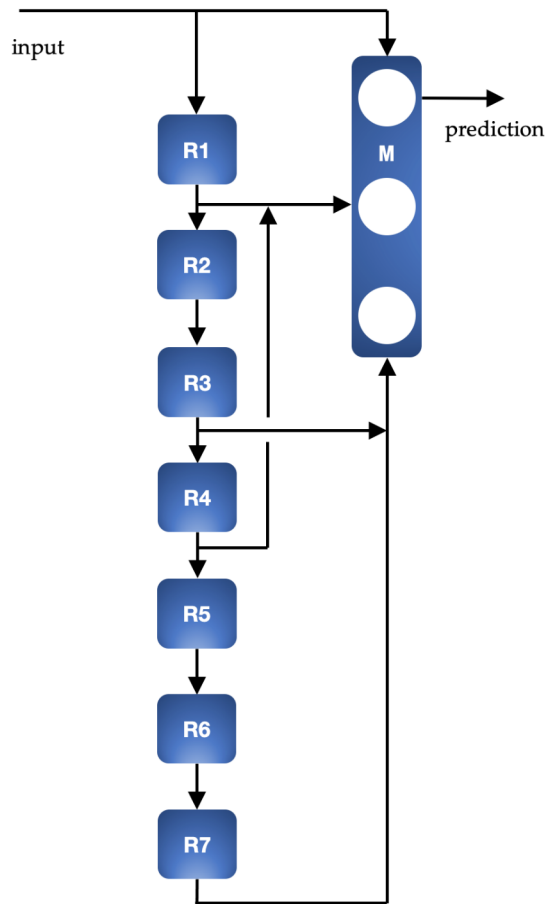
Triadic memory M learns the association of the current input, and the readout from triadic memory R.

The elementary temporal memory circuit is capable of learning simple repeating patterns, such as 60 digits of pi.

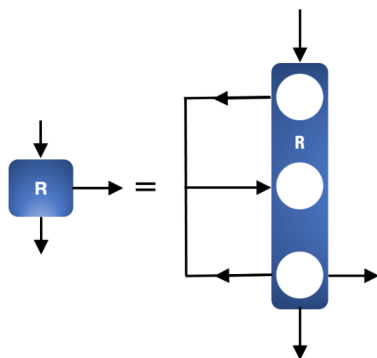
A circuit able to learn more complex patterns requires multiple feedback lines. There are infinitely many ways to design large circuits from triadic memory components. The following circuit diagram shows an example built from eight triadic memory units. The units R1 to R7 encode inputs to bigrams, bigrams to 3grams, and so on. At each step, feedback from the previous step is added to the inputs.

A readout memory M aggregates the state of several encoding states to learn the predicted value at each step.

This circuit design resembles an architecture known as reservoir computing, where a network involving multiple feedback loops propagates a series of inputs, and a readout component attaches predictions to the state of the reservoir.



In the above diagram, the circuit components R represent triadic memory units with feedback loops as follows:



This component consists of a single triadic memory and a triple of SDRs that persist the state of the component at each time step. It processes a stream of SDRs, returning an SDR which encodes the current input SDR and the previous SDR plus feedback from the previous step.

```

R[f_Symbol, {n_Integer, p_Integer}] := Module[ {T, x, y, z, overlap},

  (* instantiate a triadic memory unit *)
  TriadicMemory[T, {n, p}];

  overlap[a_SparseArray, b_SparseArray] := Total[BitAnd[a, b]];

  x = y = z = SparseArray[{0}, {n}];

  (* reset x, y, z *)
  f[SparseArray[{0}, {n}]] := x = y = z = SparseArray[{0}, {n}];

  f[input_SparseArray] := Module[ {},

    x = BitOr[y, z]; (* binarize x and y using ranked-max algorithm *)
    y = input;

    If[Total[x] > 0 && overlap[T[_], y, z = T[x, y, _]], x] < p , T[x, y, z = T[]]];
    z
  ];

];

```

The deep temporal memory circuit includes a chain of components R, generating bigrams from the inputs, trigrams from bigrams, etc. The readout memory M learns a prediction based on the temporal state of the encoding chain.

```

TemporalMemory[t_Symbol, {n_Integer, p_Integer}] :=

Module[
  {M, R1, R2, R3, R4, R5, R6, R7, x, y, z, t1, t2, t3, t4, t5, t6, t7, t8},

  (* predictions / readout memory *)
  TriadicMemory[M, {n, p}];

  (* bigram encoder units *)
  R[#, {n, p}] & /@ {R1, R2, R3, R4, R5, R6, R7};

  (* initialize state variables with null vectors *)
  x = y = z = t1 = t2 = t3 = t4 = t5 = t6 = t7 = M[0];

  Print["init ", Sort[Flatten[t7["NonzeroPositions"]]]];

  t[inp_] := Module[{},

    (* flush state if input is zero - needed when used
       as a sequence memory *)If[Total[inp] == 0, x = y = z = M[0]];

    (* store new prediction if necessary *)
    If[z != inp, M[x, y, inp]];

    (* encoding chain *)
    t1 = R1[inp];
    t2 = R2[t1];
    t3 = R3[t2];
    t4 = R4[t3];
    t5 = R5[t4];
    t6 = R6[t5];
    t7 = R7[t6];

    (* prediction readout from t1, t3, t4 and t7 *)
    z = M[x = BitOr[t1, t4], y = BitOr[t3, t7], _]

  ]

];

```

## Configuration

```

Get[ $UserBaseDirectory <> "/TriadicMemory/triadicmemoryC.m"]

n = 1000; p = 5;

```



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