

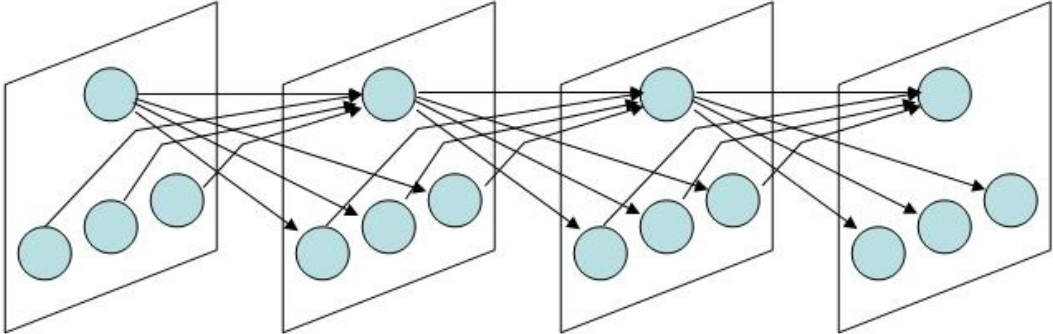
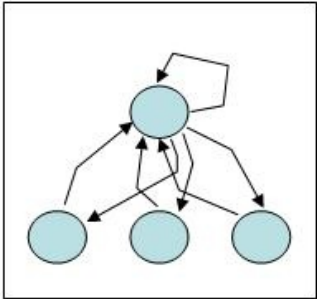
# **Recurrent Neural Networks**

Thomas Breuel

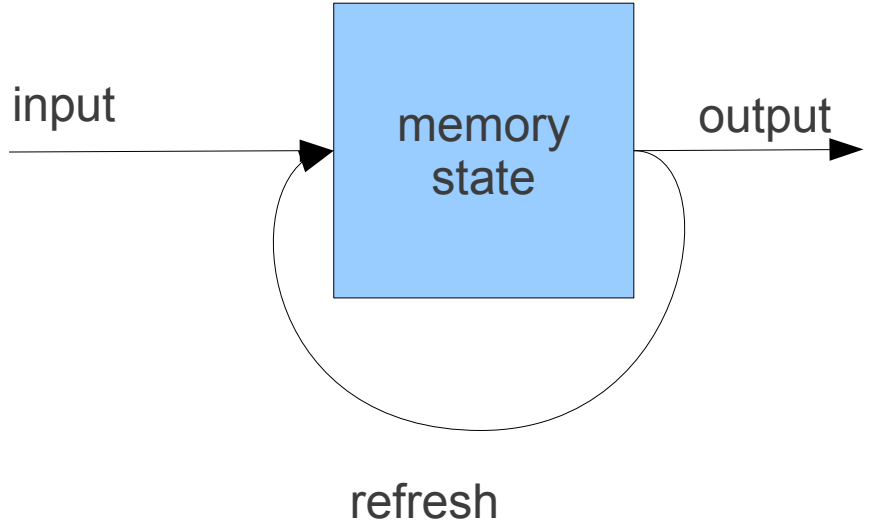
# backpropagation through time

- **“traditional” backpropagation**
- **output at time  $t$  becomes input at time  $t+1$**
- **gradient descent now needs to take time into account**
- **“vanishing gradient problem”**

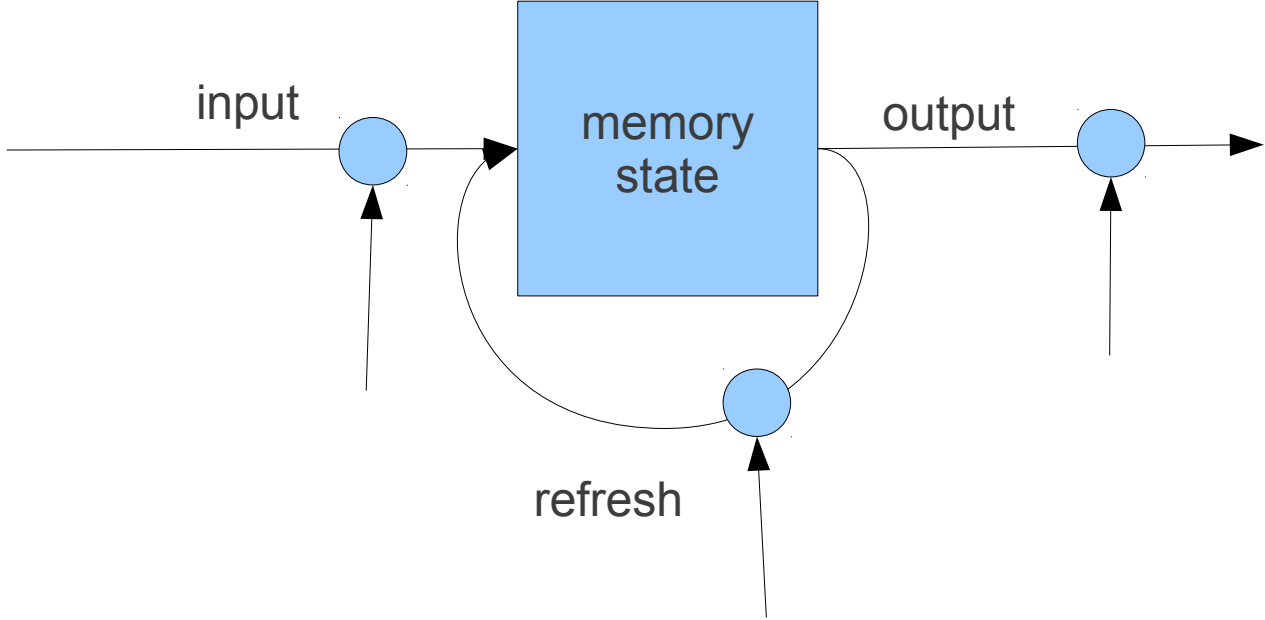
# backpropagation through time



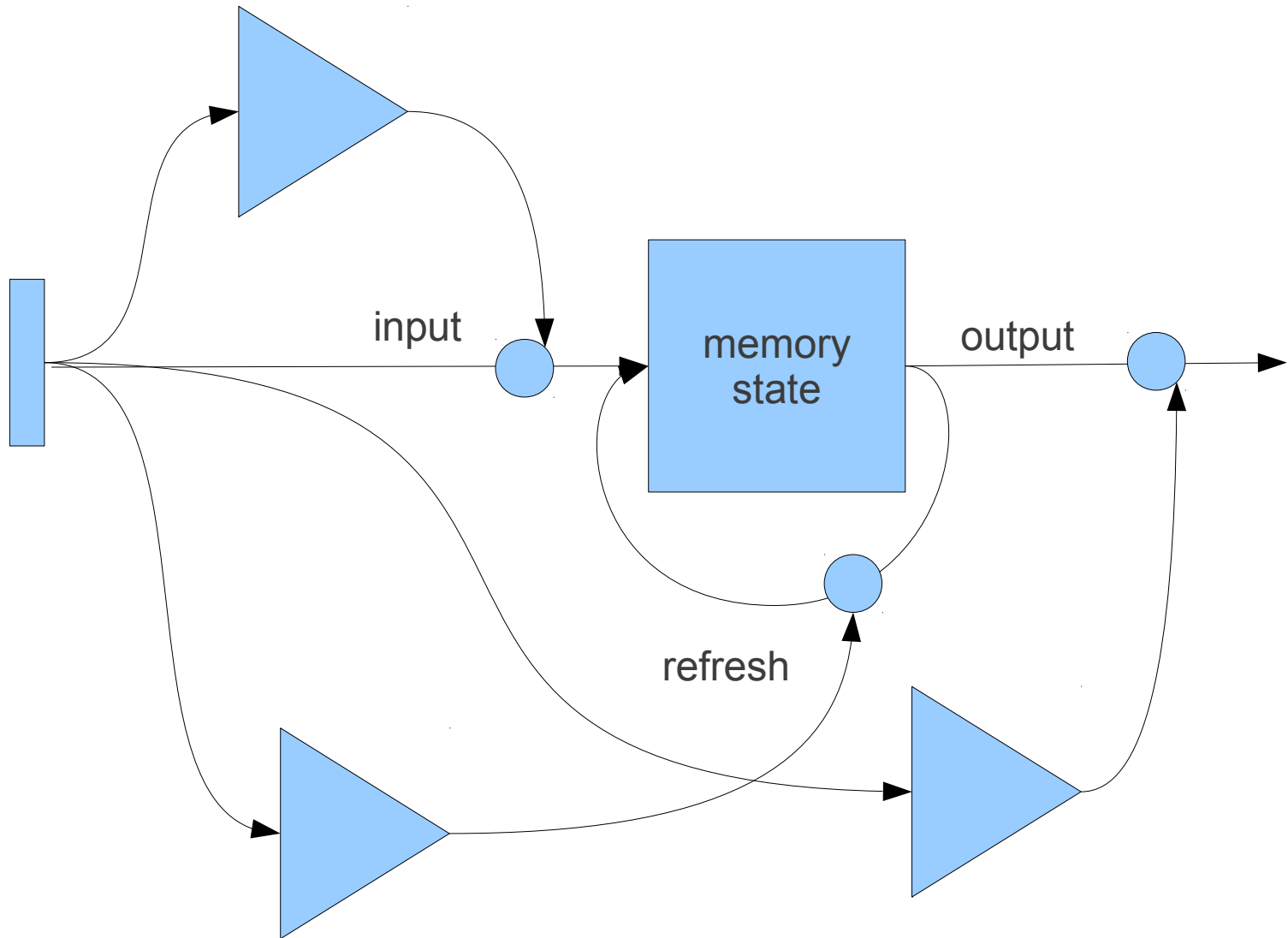
# memory cell



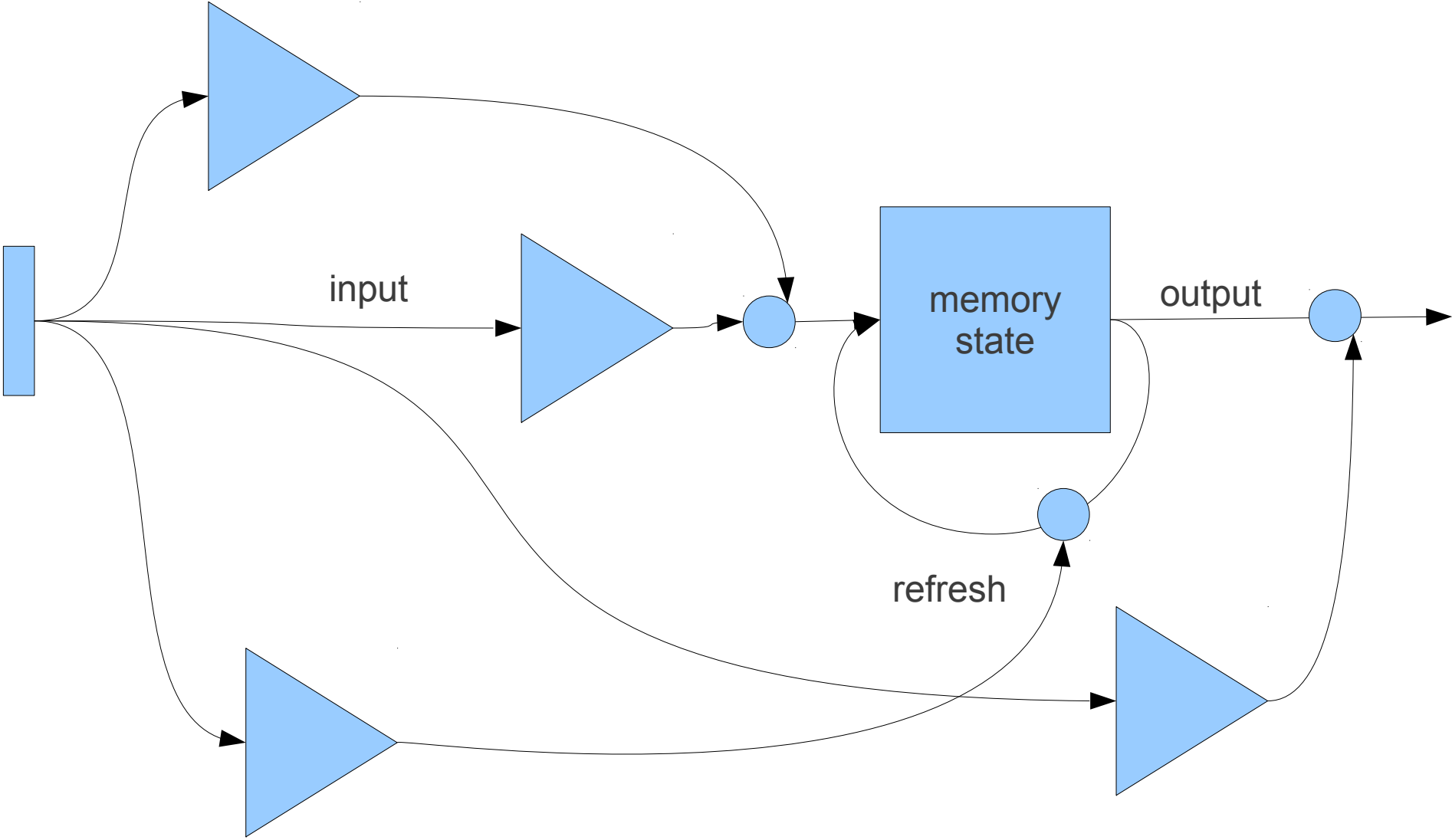
# switchable memory cell



# trainable switchable memory cell



# LSTM memory cell



# LSTM memory...

- **addresses the vanishing gradient problem**
- **solves many sequence learning tasks that are not solved by...**
  - fixed time window classification
  - recurrent neural networks