CLAIMS

What is claimed is:

1. A decoder for decoding a codeword of a Tunstall code, the decoder comprising:

a sub-decoder configured to receive an input codeword of the Tunstall code to the decoder and output a decoded symbol of the input codeword;

a symbol memory configured to receive and store the decoded symbol of the input codeword from the sub-decoder; and

a controller configured to control the symbol memory to output one or more decoded symbols stored in the symbol memory,

wherein the sub-decoder comprises:

a node memory configured to store, for a plurality of nodes of a Tunstall tree of the Tunstall code corresponding to a first level of the Tunstall tree, a plurality of codewords of the Tunstall code assigned to the plurality of nodes, respectively; and

a comparator configured to compare the input codeword with the plurality of codewords assigned to the plurality of nodes corresponding to the first level of the Tunstall tree received from the node memory, determine one of the plurality of nodes corresponding to the first level of the Tunstall tree as a determined node for the first level of the Tunstall tree based on the comparison; and produce the decoded symbol of the input codeword with respect to the first level of the Tunstall tree based on the determined node,

wherein the sub-decoder is further configured to:

determine whether the determined node for the first level of the Tunstall tree has associated therewith a descendant node, the descendant node being two levels down from the determined node according to the Tunstall tree; and

obtain an address of a plurality of nodes of the Tunstall tree corresponding to a next level of the Tunstall tree with respect to the first level of the Tunstall tree based on determining that the determined node for the first level of the Tunstall tree has associated therewith the descendent node.

2. The decoder according to claim 1, wherein the sub-decoder further comprises a selector communicatively coupled to the comparator and the node memory and configured to perform said determine whether the determined node for the first level of the Tunstall tree has associated therewith the descendant node and said obtain the address of the plurality of nodes of the Tunstall tree corresponding to the next level of the Tunstall tree.

3. The decoder according to claim 1 or 2, further comprising one or more additional sub-decoders, wherein

the sub-decoder is a first sub-decoder is associated with the first level of the Tunstall tree,

the one or more additional sub-decoders are associated with one or more additional levels of the Tunstall tree, respectively,

each of the one or more additional sub-decoders is configured to receive the input codeword and output a decoded symbol of the input codeword with respect to the level of the Tunstall tree associated with the additional sub-decoders and comprises:

a node memory configured to store, for a plurality of nodes of the Tunstall tree of the Tunstall code corresponding to the level of the Tunstall tree associated with the additional sub-decoder, a plurality of codewords of the Tunstall code assigned to the plurality of nodes, respectively; and

a comparator configured to compare the input codeword with the plurality of codewords assigned to the plurality of nodes corresponding to the level of the Tunstall tree associated with the additional sub-decoder received from the node memory and produce a decoded symbol of the input codeword with respect to the level of the Tunstall tree associated with the additional sub-decoder based on the comparison.

4. The decoder according to claim 3, wherein said produce the decoded symbol of the input codeword with respect to the level of the Tunstall tree associated with the additional sub-decoder comprises:

determining one of the plurality of nodes corresponding to the level of the Tunstall tree as a determined node for the level of the Tunstall tree based on the comparison; and

producing the decoded symbol of the input codeword with respect to the level of the Tunstall tree associated with the additional sub-decoder based on the determined node.

5. The decoder according to claim 4, wherein

the first sub-decoder is configured to, based on determining that the determined node for the first level of the Tunstall tree associated with the first sub-decoder has associated therewith the descendent node, output the address of the plurality of nodes corresponding to the next level of the Tunstall tree with respect to the first level of the Tunstall tree to an additional sub-decoder of the one or more additional sub-decoders associated with the next level of the Tunstall tree for the comparator of the additional sub-decoder to compare the input codeword with the plurality of codewords assigned to the plurality of nodes corresponding to the next level of the Tunstall tree received from the node memory of the additional sub-decoder based on the address of the plurality of nodes received and produce the decoded symbol of the input codeword with respect to the next level of the Tunstall tree associated with the additional sub-decoder based on the comparison, and

the additional sub-decoder is further configured to output the decoded symbol of the input codeword with respect to the next level of the Tunstall tree associated with the additional sub-decoder to the symbol memory.

6. The decoder according to claim 4 or 5, wherein

each additional sub-decoder of the one or more additional sub-decoders is configured to, based on determining that the determined node for the level of the Tunstall tree associated with the additional sub-decoder has associated therewith the descendent node, output an address of the plurality of nodes corresponding to a next level of the Tunstall tree with respect to the level of the Tunstall tree to another additional sub-decoder associated with the next level of the Tunstall tree for the comparator of said another additional sub-decoder to compare the input codeword with the plurality of codewords assigned to the plurality of nodes corresponding to the next level of the Tunstall tree received from the node memory of said another additional sub-decoder based on the address of the plurality of nodes received and produce the decoded symbol of the input codeword with respect to the next level of the Tunstall tree based on the comparison, and

said another additional sub-decoder is further configured to output the decoded symbol of the input codeword with respect to the next level of the Tunstall tree to the symbol memory.

7. The decoder according to claim 4, wherein

each sub-decoder of the first sub-decoder and the one or more additional sub-decoders is configured to, based on determining that the determined node for the level of the Tunstall tree associated with the sub-decoder does not have associated therewith the descendent node, determine whether the determined node for the level of the Tunstall tree associated with the sub-decoder has associated therewith a child node, wherein the child node is one level down from the determined node according to the Tunstall tree, and

the decoder further comprises a subtractor configured to, based on the sub-decoder determining that the determined node for the level of the Tunstall tree associated with the sub-decoder has associated therewith the child node, produce a decoded symbol of the input codeword with respect to a next level of the Tunstall tree with respect to the level of the Tunstall tree based on the input codeword and the codeword assigned to the determined node for the level of the Tunstall tree associated with the sub-decoder.

8. The decoder according to claim 1 or 2, wherein the node memory is configured to store, for each level of a plurality of levels of the Tunstall tree, including the first level of the Tunstall tree, and for a plurality of nodes of the Tunstall tree corresponding to the level of the Tunstall tree, a plurality of codewords of the Tunstall code assigned to the plurality of nodes corresponding to the level of the Tunstall tree, respectively.

9. The decoder according to claim 8, wherein

the comparator is configured to, based on the sub-decoder determining that the determined node for a level of the Tunstall tree has associated therewith the descendent node:

compare the input codeword with the plurality of codewords assigned to the plurality of nodes of the Tunstall tree corresponding to a next level of the Tunstall tree with respect to the level of the Tunstall tree received from the node memory based on an address of the plurality of nodes of the Tunstall tree corresponding to the next level of the Tunstall tree;

determine one of the plurality of nodes corresponding to the next level of the Tunstall tree as a determined node for the next level of the Tunstall tree based on the comparison; and

produce a decoded symbol of the input codeword with respect to the next level of the Tunstall tree based on the determined node for the next level of the Tunstall tree, and

the sub-decoder is further configured to output the decoded symbol of the input codeword with respect to the next level of the Tunstall tree to the symbol memory.

10. The decoder according to claim 8, wherein

the sub-decoder is further configured to, based on determining that the determined node for a level of the Tunstall tree does not have associated therewith the descendent node, determine whether the determined node for the level of the Tunstall tree has associated therewith a child node, wherein the child node is one level down from the determined node according to the Tunstall tree, and

the decoder further comprises a subtractor configured to, based on the sub-decoder determining that the determined node for the level of the Tunstall tree has associated therewith the child node, produce a decoded symbol of the input codeword with respect to a next level of the Tunstall tree with respect to the level of the Tunstall tree based on the input codeword and the codeword assigned to the determined node for the level of the Tunstall tree.

11. The decoder according to any one of claims 1 to 10, wherein

the symbol memory comprises a plurality of memory banks, each memory bank being configured to store one or more decoded symbols of a corresponding codeword, and

the controller is configured to control the symbol memory to output, for each of the plurality of memory banks, the one or more decoded symbols of the corresponding codeword stored in the memory bank.

12. The decoder according to any one of claims 1 to 11, wherein

the input codeword corresponds to compressed quantized weights of a neural network, and

the one or more decoded symbols of the input codeword stored in the symbol memory and output from the decoder correspond to uncompressed quantized weights of the neural network.

13. The decoder according to any one of claims 1 to 12, wherein the decoder is an integrated circuit.

14. A decoder according to claim 1, further comprising:

the symbol memory comprising a plurality of memory entries, each memory entry having stored therein one or more decoded symbols of a codeword of the Tunstall code corresponding to the memory entry; and

the controller configured to receive the input codeword of the Tunstall code to the decoder and control the symbol memory to output the one or more decoded symbols stored in one of the plurality of memory entries corresponding to the input codeword.

15. The decoder according to claim 14, wherein

the symbol memory is an on-chip memory,

the controller is communicatively coupled to the symbol memory and an off-chip memory, wherein the plurality of memory entries of the symbol memory have stored therein the one or more decoded symbols of a first plurality of codewords of the Tunstall code, respectively, and the off-chip memory has stored therein, for each of a second plurality of codewords of the Tunstall code, one or more decoded symbols of the codeword, and

the controller is configured to determine whether the one or more decoded symbols of the input codeword is located in the symbol memory or the off-chip memory, and control the determined one of the symbol memory and the off-chip memory to output the one or more decoded symbols of the input codeword.

16. The decoder according to claim 15, wherein the plurality of memory entries of the symbol memory are updated with one or more decoded symbols of a plurality of remapped codewords, respectively, the plurality of remapped codewords being at a plurality of codebook entries of an updated codebook replacing a plurality of codewords previously thereat having highest frequency counts.

17. The decoder according to any one of claims 14 to 16, wherein each of the plurality of memory entries of the symbol memory has further stored therein a symbol number parameter indicating the number of decoded symbols of a corresponding codeword stored in the memory entry.

18. A method of operating the decoder for decoding a codeword of a Tunstall code according to any one of claims 1 to 17, the method comprising:

receiving, by the sub-decoder of the decoder, an input codeword of the Tunstall code to the decoder;

outputting, by the sub-decoder, a decoded symbol of the input codeword;

receiving and storing, by the symbol memory of the decoder, the decoded symbol of the input codeword from the sub-decoder; and

controlling, by the controller of the decoder, the symbol memory to output one or more decoded symbols stored in the symbol memory,

wherein the method further comprises comparing, by the comparator of the sub-decoder, the input codeword with the plurality of codewords assigned to the plurality of nodes corresponding to the first level of the Tunstall tree received from the node memory of the sub-decoder and producing, by the comparator, the decoded symbol of the input codeword with respect to the first level of the Tunstall tree based on the comparison.