

CLAIMS

What is claimed is:

1. A computer program product comprising executable code stored in a non-transitory computer readable medium, the executable code being executable on one or more computer processors to implement an artificial neural network for use in processing output of a quantitative polymerase chain reaction (qPCR) instrument, the qPCR instrument being configured to generate amplification data from one or more qPCR assays conducted using the qPCR instrument, the artificial neural network comprising:

an input layer configured to receive input data obtained from amplification data corresponding to fluorescence values measured after each cycle of a plurality of thermal cycles of the qPCR instrument;

a plurality of hidden layers comprising one or more convolutional layers; and

an output layer;

wherein:

the artificial neural network is configured to use input data corresponding to a particular biological sample processed by the qPCR instrument to determine an amplification classification selected from a plurality of possible amplification classifications of the biological sample.

2. The computer program product of claim 1 wherein the input data comprises, at each of a plurality of cycles, normalized fluorescence values and one or more derivative values of a curve fit to the amplification data.
3. The computer program product of claim 2 wherein the curve fit to the amplification data is a curve fit to the normalized fluorescence values.
4. The computer program product of claim 2 wherein the one or more derivative values comprises at least three derivative values.
5. The computer program product of claim 2 wherein the one or more derivative values comprises at least four derivative values.
6. The computer program product of any one of claims 1-5 wherein the plurality of hidden layers comprises one or more separable convolutional layers.
7. The computer program product of any one of claims 1-5 wherein the plurality of hidden layers comprises one or more separable convolutional layers and one or more normal convolutional layers.
8. The computer program product of claim 1 wherein the plurality of hidden layers further comprises a plurality of fully connected layers.
9. The computer program product of any one of claims 1-7 wherein the plurality of hidden layers comprises pooling layers but do not comprise any fully connected layers.

10. The computer program product of any of one of claims 1-9 wherein the plurality of possible amplification classifications comprises amplified, not amplified, and inconclusive.

11. The computer program product of any of one of claims 1-10 wherein an amplification classification of each of the possible amplification classifications is expressed as a probability.

12. A method of training an artificial neural network to process output of a quantitative polymerase chain reaction (qPCR) instrument, the qPCR instrument being configured to generate amplification data from one or more qPCR assays conducted using the qPCR instrument, the artificial neural network being processed to use the amplification data to classify, using a plurality of classifications, an amplification result corresponding to the amplification data, the method comprising:

providing to the artificial neural network training amplification data obtained from conducting qPCR on training samples;

determining a class weight for each of the plurality of classifications wherein the class weight corresponds to a portion of training sample belonging to each classification of the plurality of classifications;

using the class weight to obtain a class-weighted error determination corresponding to a classification determination made by the artificial neural network for a particular training sample; and

using the class-weighted error determination to adjust parameter values of the artificial neural network to reduce error.

13. The method of claim 12 wherein a plurality of respective class-weighted error determinations corresponding to a plurality of respective classifications more heavily weights a classification that is less represented in the training data than it weights another of the plurality of classifications that is more represented in the training data.

14. The method of any one of claims 12-13 wherein the plurality of classifications comprises amplified, not amplified, and inconclusive.

15. The method of any one of claims 12-14 wherein each of the plurality of classifications is expressed as a probability.

16. The method of any one of claims 12-15 wherein a cross-entropy loss function is used in combination with a class weight to obtain the class-weighted error determination.

17. A computer program product comprising executable code stored in a non-transitory computer readable medium, the executable code being executable on one

or more computer processors to process output of a quantitative polymerase chain reaction (qPCR) instrument using an artificial neural network, the qPCR instrument being configured to generate amplification data from one or more qPCR assays conducted using the qPCR instrument, the executable code being executable on the one or more computer processors to pre-process amplification data to obtain pre-processed data to provide as input data to an input layer of the artificial neural network, the pre-processing comprising:

determining if the amplification data corresponds to a number of cycles of the qPCR instrument that is different than a size of a corresponding dimension of an input layer of the artificial neural network; and

if the number of cycles is different than the size, then fitting the pre-processed data to the size.

18. The computer program product of claim 17 wherein fitting the pre-processed data to the size comprises truncating the amplification data such that truncated data fits the size.

19. The computer program product of claim 17 wherein fitting the pre-processed data to the size comprises interpolating the amplification data such that interpolated data fits the size.

20. The computer program product of claim 18 wherein the pre-processed data further comprises one or more derivative values for each cycle represented in the

truncated data, wherein the one or more derivative values are determined based on a curve fit to non-truncated data.

21. The computer program product of claim 19, wherein the pre-processed data further comprises one or more derivative values for each cycle represented in the interpolated data, wherein the one or more derivative values are determined based on a curve fit to non-interpolated data.

22. The computer program product of any one of claims 17-21 wherein the artificial neural network comprises one or more convolutional layers.

23. A quantitative polymerase chain reaction (qPCR) system comprising:

a qPCR instrument configured to process biological samples and generate amplification data corresponding the samples; and

one or more computers configured to receive the amplification data and to receive, store, and execute the executable instruction code of the computer program product of any one of claims 1-11 and 17-22.