CLAIMS

What is claimed is:

1. A method comprising:

receiving, by a computing device, training data comprising a plurality of input images, wherein each input image of the plurality of input images comprises at least one sub-visible particle (SVP);

generating, based on the plurality of input images, a plurality of training images, wherein each training image of the plurality of training images comprises at least one SVP; and

training, based on the plurality of training images, a convolutional neural network (CNN), wherein the trained CNN is configured to classify one or more SVPs in one or more testing images as comprising a first SVP type or a second SVP type,

wherein the training data comprises image metadata associated with the plurality of input images, and wherein the image metadata is indicative of a location of the at least one SVP in each input image of the plurality of input images.

2. The method of claim 1, wherein the plurality of input images comprises a plurality of flow imaging microscope images associated with a pharmaceutical product.

3. The method of claim 1, wherein the image metadata associated with the plurality of input images is indicative of an initial classification of the at least one SVP.

4. The method of claim 1, wherein at least one of:

the at least one SVP comprises a protein particle, a silicon particle, a fiber particle, an air bubble, a glass particle, or other known particle type;

the at least one SVP comprises an equivalent circular diameter ranging from 1.125 to 130 micrometers;

each training image of the plurality of training images comprises a size of at least 64x64 pixels;

the first SVP type comprises protein; or

the second SVP type comprises silicon.

5. The method of claim 1, wherein the trained CNN comprises at least three hidden layers.

6. The method of claim 5, wherein each hidden layer of the at least three hidden layers comprises at least one filter comprising a size of at least 3x3 pixels.

7. The method of claim 1, wherein training the CNN further comprises determining a plurality of hyperparameters, and wherein the plurality of hyperparameters comprises one or more of: a batch size ranging from 64 to 256 or a dropout rate ranging from 5% to 50%.

8. The method of claim 1, wherein training the CNN further comprises determining an activation function, and wherein the activation function comprises a rectified linear units activation function or a hyperbolic tangent activation function.

9. A method comprising:

receiving, by a computing device, training data comprising at least one input image comprising at least one sub-visible particle (SVP);

generating, based on the at least one input image, at least one preprocessed image;

determining, by a trained convolutional neural network (CNN), based on the at least one preprocessed image, a classification of the at least one SVP; and

outputting, by the trained CNN, an indication of the classification of the at least one SVP,

wherein the training data comprises image metadata associated with the at least one input image, and wherein the image metadata is indicative of a location of the at least one SVP in each input image of the at least one input image.

10. The method of claim 9, wherein the at least one input image comprises at least one flow imaging microscope image associated with a pharmaceutical product.

11. The method of claim 9, further comprising:

verifying the location of the at least one SVP indicated in the image metadata.

12. The method of claim 9, wherein generating the at least one preprocessed image comprises at least one of:

resizing the at least one input image to at least 64x64 pixels; or

determining, based on at least one segmentation algorithm a location of the at least one SVP.

13. The method of claim 9, wherein the trained CNN comprises at least three hidden layers, and wherein each hidden layer of the at least three hidden layers comprises at least one filter comprising a size of at least 3x3 pixels.

14. The method of claim 9, wherein the trained CNN comprises a plurality of hyperparameters, and wherein the plurality of hyperparameters comprises one or more of:

a batch size ranging from 64 to 256 or a dropout rate ranging from 5% to 50%.

15. The method of claim 9, wherein the trained CNN comprises an activation function and, wherein the activation function comprises a rectified linear units activation function or a hyperbolic tangent activation function.

16. A method comprising:

receiving, by a computing device, training data comprising at least one input image comprising a plurality of sub-visible particles (SVPs);

generating, based on the at least one input image, a plurality of preprocessed images, wherein each preprocessed image of the plurality of preprocessed images comprises one of the plurality of SVPs;

determining, by a trained convolutional neural network (CNN), based on the plurality of preprocessed images, a classification of each SVP of the plurality of SVPs; and

outputting, by the trained CNN, an indication of the classification of each SVP of the plurality of SVPs,

wherein the training data comprises image metadata associated with the at least one input image, and wherein the image metadata is indicative of a location of the at least one SVP in each input image of the at least one input image.

17. The method of claim 16, further comprising: determining, based on at least one segmentation algorithm, a location of each SVP of the plurality of SVPs.

18. The method of claim 16, wherein the at least one input image comprises at least one flow imaging microscope image associated with a pharmaceutical product.

19. The method of claim 18, further comprising:

verifying the location of the at least one SVP indicated in the image metadata,

wherein the image metadata comprises metadata associated with the at least one flow imaging microscope image and is indicative of an initial classification of the at least one SVP.

20. The method of claim 16, wherein at least one of:

the plurality of SVPs comprises protein particles, silicon particles, fiber particles, air bubbles, or glass particles;

each SVP of the plurality of SVPs comprises an equivalent circular diameter ranging from 1.125 to 130 micrometers; or

the CNN is trained using training image that each comprise a size of at least 64x64 pixels.