

CLAIMS:

1. A fluid quality measurement device ~~(100)~~, comprising:

at least one processor ~~(101)~~; and

5 at least one memory ~~(102)~~ including computer program code;

the at least one memory ~~(102)~~ and the computer program code configured to, with the at least one processor ~~(101)~~, cause the fluid quality measurement device ~~(100)~~ to:

obtain a plurality of holograms ~~(204)~~, wherein each hologram in the plurality of holograms ~~(204)~~ represents a microscopic object ~~(303)~~ in a fluid sample ~~(304)~~;

15 produce a latent space representation ~~(701)~~ of each hologram in the plurality of holograms ~~(204)~~ using a trained autoencoder neural network ~~(601)~~;

assign each hologram in the plurality of holograms ~~(204)~~ to a class in a plurality of classes ~~(1000)~~ based on the latent space representation of the hologram, wherein each class in the plurality of classes ~~(1000)~~ corresponds to a partition ~~(703)~~ of the latent space ~~(700)~~; and

20 produce a fluid sample fingerprint ~~(205)~~ based on the assignment of the plurality of holograms ~~(204)~~ into the plurality of classes ~~(1000)~~, wherein the fluid sample fingerprint ~~(205)~~ comprises an indication of a concentration of microscopic objects ~~(303)~~ in the fluid sample ~~(304)~~ for each class in the plurality of classes ~~(1000)~~.

2. The fluid quality measurement device ~~(100)~~ according to claim 1, wherein the at least one memory ~~(102)~~ and the computer program code are further configured to, with the at least one processor ~~(101)~~, cause the fluid quality measurement device ~~(100)~~ to:

provide the fluid sample fingerprint ~~(205)~~ for transmission to a server ~~(400)~~; and/or

provide the fluid sample fingerprint to a user.

3. The fluid quality measurement device ~~(100)~~ according to claim 1 or claim 2, wherein the autoencoder neural network ~~(601)~~ comprises a variational autoencoder neural network or a convolutional variational autoencoder neural network.

4. The fluid quality measurement device ~~(100)~~ according to any preceding claim, wherein the at least one memory ~~(102)~~ and the computer program code are further configured to, with the at least one processor ~~(101)~~, cause the fluid quality measurement device ~~(100)~~ to:

provide a sample hologram from the plurality of holograms for at least one class in the plurality of classes ~~(1000)~~ for transmission to a server ~~(400)~~; and/or

provide a sample hologram from the plurality of holograms for at least one class in the plurality of classes ~~(1000)~~ to a user.

5. The fluid quality measurement device ~~(100)~~ according to any preceding claim, wherein the at least one memory ~~(102)~~ and the computer program code are further configured to, with the at least one processor ~~(101)~~,
5 cause the fluid quality measurement device ~~(100)~~ to provide a sample latent space representation of a hologram from the plurality of holograms for at least one class in the plurality of classes ~~(1000)~~ for transmission to a server ~~(400)~~.

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6. The fluid quality measurement device ~~(100)~~ according to any preceding claim, wherein the at least one memory ~~(102)~~ and the computer program code are further configured to, with the at least one processor ~~(101)~~,
15 cause the fluid quality measurement device ~~(100)~~ to:

assign each hologram in the plurality of holograms ~~(204)~~ to a class in a second plurality of classes ~~(1100)~~ using a trained convolutional neural network, wherein the second plurality of classes ~~(1100)~~ comprises at
20 least one class of interest; and

compute an indication of a concentration of microscopic objects corresponding to the at least one class of interest in the fluid sample ~~(304)~~ based on the assignment of the plurality of holograms ~~(204)~~ into the
25 second plurality of classes ~~(1100)~~.

7. The fluid quality measurement device according to claim 6, wherein the at least one memory ~~(102)~~ and the computer program code are further configured to,

with the at least one processor~~(101)~~, cause the fluid quality measurement device~~(100)~~ to:

provide the indication of the concentration of microscopic objects corresponding to the at least one class of interest in the fluid sample~~(304)~~ for transmission to a server~~(400)~~; and/or

provide the indication of the concentration of microscopic objects corresponding to the at least one class of interest in the fluid sample~~(304)~~ to a user.

8. The fluid quality measurement device~~(100)~~ according to any preceding claim, further comprising an imaging unit~~(202)~~ configured to produce the plurality of holograms using digital holographic microscopy.

9. A server~~(400)~~ comprising:
at least one processor~~(401)~~; and
at least one memory~~(402)~~ including computer program code;

the at least one memory~~(402)~~ and the computer program code configured to, with the at least one processor~~(401)~~, cause the server~~(400)~~ to:

receive a fluid sample fingerprint~~(205)~~ from a fluid quality measurement device~~(100)~~, wherein the fluid sample fingerprint~~(205)~~ comprises an indication of a concentration of microscopic objects in a fluid sample~~(304)~~ for each class in a plurality of classes~~(1000)~~;

compare the fluid sample fingerprint~~(205)~~ to at least one preconfigured criterion;

in response to the fluid sample fingerprint~~-(205)~~ not meeting the preconfigured criterion, provide an anomaly notification.

5 10. The server according to claim 9, wherein the at least one memory~~-(402)~~ and the computer program code are further configured to, with the at least one processor~~-(401)~~, cause the server~~-(400)~~ to compare the fluid sample fingerprint~~-(205)~~ to at least one preconfigured criterion by performing:

produce a feature space representation of the fluid sample fingerprint~~-(205)~~, wherein each dimension of the feature space~~-(1200)~~ corresponds to a class in the plurality of classes~~-(1000)~~; and

15 compare the feature space representation of the fluid sample fingerprint~~-(205)~~ to a feature space representation of at least one reference fingerprint.

20 11. The server~~-(400)~~ according to claim 10, wherein the at least one memory~~-(402)~~ and the computer program code are further configured to, with the at least one processor~~-(401)~~, cause the server~~-(400)~~ to compare the feature space representation of the fluid sample fingerprint to a feature space representation of the at least one reference fingerprint by calculating a distance metric between the fluid sample fingerprint and the at least one reference fingerprint.

30 12. The server~~-(400)~~ according to claim 11, wherein the at least one memory~~-(402)~~ and the computer program

code are further configured to, with the at least one processor~~-(401)~~, cause the server~~-(400)~~ to:

compare the calculated distance metric to a pre-configured maximum distance metric; and

5 in response to the calculated distance metric being greater than the preconfigured maximum distance metric, provide the anomaly notification.

10 13. The server~~-(400)~~ according to claim 9, wherein the at least one memory~~-(402)~~ and the computer program code are further configured to, with the at least one processor~~-(401)~~, cause the server~~-(400)~~ to compare the fluid sample fingerprint to at least one preconfigured criterion by performing:

15 compare the indication of the concentration of microscopic objects in the fluid sample of each class in the plurality of classes to a corresponding preconfigured maximum value; and

20 in response to the indication of the concentration of microscopic objects being greater than the corresponding preconfigured maximum value in at least one class, provide the anomaly notification.

25 14. A fluid monitoring system~~-(500)~~ comprising at least one fluid quality measurement device~~-(100)~~ according to any of claim 1 - 8 and a server~~-(400)~~ according to any of claims 9 - 13.

30 15. A method~~-(1400)~~ for fluid quality measurement, the method comprising:

obtaining~~-(1401)~~ a plurality of holograms, wherein each hologram in the plurality of holograms represents a microscopic object in a fluid sample;

producing~~-(1402)~~ a latent space representation of each hologram in the plurality of holograms using a trained autoencoder neural network;

assigning~~-(1403)~~ each hologram in the plurality of holograms to a class in a plurality of classes based on the latent space representation of the hologram, wherein each class in the plurality of classes corresponds to a partition of the latent space; and

producing~~-(1404)~~ a fluid sample fingerprint based on the assignment of the plurality of holograms into the plurality of classes, wherein the fluid sample fingerprint comprises an indication of a concentration of microscopic objects in the fluid sample for each class in the plurality of classes.

16. A method~~-(1500)~~ for fluid quality monitoring, the method comprising:

receiving~~-(1501)~~ a fluid sample fingerprint from a fluid quality measurement device, wherein the fluid sample fingerprint comprises an indication of a concentration of microscopic objects in a fluid sample for each class in a plurality of classes;

comparing~~-(1502)~~ the fluid sample fingerprint to at least one preconfigured criterion;

in response to the fluid sample fingerprint not meeting~~-(1503)~~ the preconfigured criterion, providing~~-(1504)~~ an anomaly notification.

17. A computer program product comprising program
code configured to perform the method according to claim
15 or claim 16 when the computer program product is
5 executed on a computer.