Claims

1. A system for analysing a sample comprising a motile cell comprising at least a head portion, the system comprising:

an input interface arranged to receive image data comprising a time series of images of the sample, the images of the sample having a first spatial resolution; and

a processing apparatus arranged to:

produce a time series of images of the cell by identifying a section of each image of the sample which contains the cell;

apply a first machine-learning algorithm to said images of the cell to generate an enhanced image of the cell having a second spatial resolution that is numerically smaller than the first spatial resolution;

apply a second machine-learning algorithm to said enhanced image of the cell to determine one or more morphological parameters of the cell;

apply a motion tracing algorithm to the time series of images of the sample to determine a motion trace of the head portion of the cell; and

use the one or more morphological parameters of the cell and the motion trace of the head portion of the cell to determine a quality metric for the cell.

2. The system of claim 1, wherein the sample comprises a plurality of motile cells, each comprising at least a head portion and the processing apparatus is arranged to:

produce a time series of images of each cell by identifying a sections of each image of the sample which contain each cell;

apply the first machine-learning algorithm to each of the plurality of time series of images of the cells to generate an enhanced image of each cell having a second spatial resolution that is numerically smaller than the first spatial resolution;

apply the second machine-learning algorithm to each enhanced image to determine one or more morphological parameters of each cell;

apply the motion tracing algorithm to the time series to determine a motion trace of the head portion of each cell; and

for each cell, use the one or more morphological parameters of the cell and the motion trace of the cell to determine a quality metric for the cell.

3. The system of claim 1 or 2, wherein the motion tracing algorithm is based on statistical analysis of intensity fluctuations in the time series of images of the sample.

4. The system of claim 3, wherein the motion tracing algorithm comprises:

selecting from the time series of images a plurality of windows, each window comprising a respective stack of spatially-coincident sections of the images;

for each window:

decomposing the window into eigenimages and corresponding values;

calculating, for each of a plurality of test points in the window, a respective first value as a first function of the eigenimages;

calculating, for each of the plurality of test points in the window, a respective second value as a second function of the eigenimages; and

determining, from the first and second values, a respective indicator value for each test point in the window, representative of a likelihood of the cell being present at a location corresponding to the test point; and

combining the indicator values to produce an output image comprising a motion trace of the cell through the time series of images.

5. The system of any preceding claim wherein the motion tracing algorithm uses a point spread function corresponding to the head portion of the cell.

6. The system of any preceding claim, wherein the second machine-learning algorithm is arranged to determine one or more morphological parameters from the following group: head portion height, head portion width, head portion length;

wherein the motile cell comprises a tail portion and optionally a midpiece portion between the head portion and the tail portion, and wherein the one or more morphological parameters determined by the second machine-learning algorithm includes one or more of: tail portion height, tail portion width, tail portion length, a ratio of a head portion or tail portion dimension to another head portion or tail portion dimension; a midpiece portion height, a midpiece portion width or a midpiece portion length, or a ratio of a head portion, tail portion or midpiece portion dimension to another head portion, tail portion or midpiece portion dimension.

7. The system of any preceding claim, wherein the second machine-learning algorithm is trained using training data comprising a set of training images of motile cells including images captured using fluorescence microscopy and a corresponding set of training morphological parameters.

8. The system of any preceding claim, wherein determining the quality metric comprises applying a third machine-learning algorithm to the one or more morphological parameters of the cell and the motion trace of the head portion of the cell

9. The system of any preceding claim, comprising a label-free microscopy imaging apparatus for capturing the time series of images of the sample

10. The system of any preceding claim, comprising a sample holder comprising one or more fiducial markers or grids with a known dimension.

11. The system of any preceding claim, arranged to analyse a sample comprising one or more human spermatozoa.

12. A computer-implemented method for analysing a sample comprising a motile cell comprising at least a head portion, the method comprising:

receiving a time series of images of the sample, the images of the sample having a first spatial resolution;

producing a time series of images of the cell by identifying a section of each image of the sample which contains the cell;

applying a first machine-learning algorithm to said images of the cell to generate an enhanced image of the cell having a second spatial resolution that is numerically smaller than the first spatial resolution;

applying a second machine-learning algorithm to said enhanced image of the cell to determine one or more morphological parameters of the cell;

applying a motion tracing algorithm to the time series of images of the sample to determine a motion trace of the head portion of the cell; and

using the one or more morphological parameters of the cell and the motion trace of the head portion of the cell to determine a quality metric for the cell.

13. Computer software that, when executed by suitable computing apparatus, causes said computing apparatus to execute the method of claim 12.

14. A method of selecting one or more motile cells from a sample comprising a plurality of motile cells comprising at least a head portion, the method comprising:

using the method of claim 12 to determine a quality metric for each cell of the plurality of cells; and

automatically selecting one or more cells from the sample based on the quality metric(s) of said cells.

15. A system for selecting one or more motile cells from a sample comprising a plurality of motile cells comprising at least a head portion, the system comprising:

the system of any of claims 1-11, arranged to determine a quality metric for each cell of the plurality of cells; and

a cell selection apparatus arranged to extract one or more cells from the sample based on the quality metric(s) of said cells.