sample, wherein the capturing of each of the time-resolved fluorescence emission spectra, the time-resolved reflectance spectra, and the time-resolved transmittance spectra is synchronized based on the emission of the excitation radiation by the plurality of light sources;

an image processing module, coupled to the imaging module, to receive information corresponding to the time-resolved fluorescence emission spectra, time-resolved reflectance, and time-resolved transmittance spectra over the spatial region of the sample, the image processing module can include: an image processor to perform spatial and temporal resolution of the information to obtain a plurality of spectral parameters, wherein the spatial resolution is to extract a spatial distribution of pathogens in the spatial region of the sample and the temporal resolution is to extract time-dependent spectral parameters of the pathogens in the sample; and a library database comprising a set of standard spectral parameters identifiable with reference pathogens, wherein the image processing module can be configured to compare each of the plurality of spectral parameters with the set of standard spectral parameters based on a first image processing model to detect and classify the pathogen, wherein the library database is to receive a new set of standard spectral parameters identifiable with a new reference pathogen; a model builder ensemble to provide a plurality of image processing models based on the new set of standard spectral parameters identifiable with the new reference pathogen and the set of standard spectral parameters identifiable with reference pathogen; and a cross-validator to fix a second image processing model from the plurality of image processing models, wherein the second image processing model is to replace the first image processing model; and

a display module to display a result based on the comparison.

[0002B] According to a second aspect of the present invention, there is provided a method for non-invasive, automatic, and in-situ detection and classification of pathogens. The method can include:

exposing a spatial region of a sample comprising a plurality of pathogens to an excitation radiation at a predetermined range of wavelengths emitted from a plurality of light sources for a predetermined duration at a predetermined periodicity;

capturing, by a detector, a time-resolved fluorescence emission spectra and at least one of: a time-resolved reflectance and a transmittance spectra at multiple spectral bands from over the spatial region of the sample, wherein the capturing of each of the time-resolved fluorescence emission spectra, the time-resolved reflectance spectra, and the time-resolved transmittance spectra is synchronized based on the emission of the excitation radiation by the plurality of light sources;

performing, by an image processing module, spatial and temporal resolution of the time-resolved fluorescence emission spectra, time-resolved reflectance, and time-resolved transmittance spectra captured over the spatial region of the sample to obtain a plurality of spectral parameters, wherein the spatial resolution is to extract a spatial distribution of pathogens in the spatial region of the sample and the temporal resolution is to extract time-dependent spectral parameters of the pathogens in the sample;

accessing, by an image processor, a library database, wherein the library database comprises a set of standard spectral parameters associated with reference pathogens;

comparing, by the image processing module, each of the plurality of spectral parameters with the set of standard spectral parameters to detect and classify the pathogens; ~~and~~

displaying, by a display module, a result based on the comparing;

receiving, by the library database, a new set of standard spectral parameters identifiable with a new reference pathogen;

providing, by a model builder ensemble, a plurality of image processing models based on the new set of standard spectral parameters identifiable with the new reference

pathogen and the set of standard spectral parameters identifiable with reference pathogen; and

fixing, by a cross-validator, a second image processing model from the plurality of image processing models, wherein the second image processing model is to replace a first image processing model, wherein the first image processing model is associated with the set of standard spectral parameters and the second image processing model is associated with the set of standard spectral parameters and the new set of standard spectral parameters.

BRIEF DESCRIPTION OF DRAWINGS

[0001] The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The same numbers are used throughout the drawings to reference like features and components.

[0002] Fig. 1 depicts a schematic representation of a device for detection and classification of pathogens, in accordance with an implementation of the present subject matter.

[0003] Fig. 2 depicts schematic representation of an imaging module, in accordance with an implementation of the present subject matter.

I/We claim:

1. A device for non-invasive, automatic, and in-situ detection and classification of pathogens, the device comprising:

an imaging module comprising:

a plurality of light sources, wherein each light source is to emit excitation radiation at a predetermined range of wavelengths;

an optical switch to expose a spatial region of a sample comprising pathogens to the excitation radiation for a predetermined duration at a predetermined periodicity; and

a detector to capture time-resolved fluorescence emission spectra and at least one of: time-resolved reflectance and time-resolved transmittance spectra at multiple spectral bands over the spatial region of the sample, wherein the capturing of each of the time-resolved fluorescence emission spectra, the time-resolved reflectance spectra, and the time-resolved transmittance spectra is synchronized based on the emission of the excitation radiation by the plurality of light sources;

an image processing module coupled to the imaging module to receive information corresponding to the time-resolved fluorescence emission spectra, time-resolved reflectance, and time-resolved transmittance spectra over the spatial region of the sample, the image processing module comprising:

an image processor to perform spatial and temporal resolution of the information to obtain a plurality of spectral parameters, wherein the spatial resolution is to extract a spatial distribution of pathogens in the spatial region of the sample and the temporal resolution is to extract time-dependent spectral parameters of the pathogens in the sample; and

a library database comprising a set of standard spectral parameters identifiable with reference pathogens,

wherein the image processing module is to compare each of the plurality of spectral parameters with the set of standard spectral parameters based on a first image processing model to detect and classify the pathogen, wherein the

library database is to receive a new set of standard spectral parameters identifiable with a new reference pathogen;

a model builder ensemble to provide a plurality of image processing models based on the new set of standard spectral parameters identifiable with the new reference pathogen and the set of standard spectral parameters identifiable with reference pathogen; and

a cross-validator to fix a second image processing model from the plurality of image processing models, wherein the second image processing model is to replace the first image processing model; and

a display module to display a result based on the comparison.

~~2. The device as claimed in claim 1, wherein the image processing module is to compare each of the plurality of spectral parameters with the set of standard spectral parameters based on a first image processing model and wherein the library database is to receive a new set of standard spectral parameters identifiable with a new reference pathogen, wherein the device comprises:~~

~~a model builder ensemble to provide a plurality of image processing models based on the new set of standard spectral parameters identifiable with the new reference pathogen and the set of standard spectral parameters identifiable with reference pathogen; and~~

~~a cross-validator to fix a second image processing model from the plurality of image processing models, wherein the second image processing model is to replace the first image processing model.~~

2~~3~~. The device as claimed in claim 1, wherein the plurality of light sources comprises at least one of the following: a light emitting diode, a laser, a colored light source, a configurable light source, ambient light, or any combination thereof.

3~~4~~. The device as claimed in claim 1, wherein the time-resolved fluorescence emission spectra is fluorescence lifetime spectrum or photobleaching spectrum.

4~~5~~. The device as claimed in claim 3~~4~~, wherein the detector is to capture: a steady-state fluorescence spectrum in combination with at least one of: the fluorescence lifetime spectrum, the photobleaching spectrum, the time-resolved reflectance spectrum, and the time-resolved transmittance spectrum.

56. The device as claimed in claim 34, wherein the detector is to capture fluorescence life time spectra, wherein the excitation radiation has the predetermined duration in the range from 1 ps to 1 s and the predetermined periodicity in the range from 0.01 ns to 1 s.

67. The device as claimed in claim 34, wherein the detector is to capture photobleaching spectra, wherein the excitation radiation has the predetermined duration in the range from 1 ms to 10 s and the predetermined periodicity in the range from 0.01s to 1 min.

78. The device as claimed in claim 1, wherein the image processing module is to classify the pathogen based on family, genus, species and strain based on the comparison.

89. The device as claimed in claim 1, wherein the image processing module is to quantify pathogens present in the sample, wherein the image processing module is to receive an intensity of the time-dependent fluorescence of the sample and compare the intensity with a fluorescence intensity data provided in the library database to quantify pathogens.

910. The device as claimed in claim 1, wherein based on the detection and classification of pathogens, the device is to monitor wound healing and wound closure, wherein the device is to calculate at least one of the following: wound size, wound depth, wound temperature distribution, tissue classification, biofilm information, degree of contamination, tissue oxygenation and blood flow.

101. The device as claimed in claim 1, wherein the plurality of spectral parameters comprises ratios of amplitude of fluorescence emission spectra, ratios of amplitude of reflectance spectra, ratios of amplitude of transmittance spectra, bandwidth of the fluorescence emission spectra, full width half maxima of the fluorescence emission spectra, and combinations thereof.

112. The device as claimed in claim 1, wherein the library database comprises at least one of excitation emission matrix spectra, excitation emission matrix fluorescence spectra, reflectance spectra, transmittance spectra, fluorescence life times, photobleaching times, absorption coefficients, reflection coefficients, transmission coefficients, scattering coefficients, normalized intensity data, intensity ratios, or any combinations thereof, identifiable with various reference pathogens.

123. The device as claimed in claim 1, wherein the device is a handheld device.

134. The device as claimed in claim 1, wherein the image processor is to obtain at least one of the following: fluorescence decay times, fluorescence emission signal amplitude, photobleaching times, or any combination thereof.

145. The device as claimed in claim 1, wherein the result comprises at least one of the following: detection of presence of various pathogens on the sample, pathogen spatial distribution data, pathogen growth state data, co-colonization data, biofilm information, biomarker information, pathogen quantification data, a treatment protocol, or any combination thereof.

156. A method for non-invasive, automatic, and in-situ detection and classification of pathogens comprising:

exposing a spatial region of a sample comprising a plurality of pathogens to an excitation radiation at a predetermined range of wavelengths emitted from a plurality of light sources for a predetermined duration at a predetermined periodicity;

capturing, by a detector, a time-resolved fluorescence emission spectra and at least one of: a time-resolved reflectance and a transmittance spectra at multiple spectral bands from over the spatial region of the sample, wherein the capturing of each of the time-resolved fluorescence emission spectra, the time-resolved reflectance spectra, and the time-resolved transmittance spectra is synchronized based on the emission of the excitation radiation by the plurality of light sources;

performing, by an image processing module, spatial and temporal resolution of the time-resolved fluorescence emission spectra, time-resolved reflectance, and time-resolved transmittance spectra captured over the spatial region of the sample to obtain a plurality of spectral parameters, wherein the spatial resolution is to extract a spatial distribution of pathogens in the spatial region of the sample and the temporal resolution is to extract time-dependent spectral parameters of the pathogens in the sample;

accessing, by an image processor, a library database, wherein the library database comprises a set of standard spectral parameters associated with reference pathogens;

comparing, by the image processing module, each of the plurality of spectral parameters with the set of standard spectral parameters to detect and classify the pathogens; and

displaying, by a display module, a result based on the comparing;

receiving, by the library database, a new set of standard spectral parameters identifiable with a new reference pathogen;

providing, by a model builder ensemble, a plurality of image processing models based on the new set of standard spectral parameters identifiable with the new reference pathogen and the set of standard spectral parameters identifiable with reference pathogen; and

fixing, by a cross-validator, a second image processing model from the plurality of image processing models, wherein the second image processing model is to replace a first image processing model, wherein the first image processing model is associated with the set of standard spectral parameters and the second image processing model is associated with the set of standard spectral parameters and the new set of standard spectral parameters.

167. The method as claimed in claim 156, wherein the method comprises:

computing, by the image processing module, real time spatial distribution data of the pathogens across a wound region;

combining, by the image processing module, the real time spatial distribution data of the pathogens across the wound region with fluorescence intensity data at a plurality of spectral bands of the corresponding pathogens contained in the library database; and

quantifying, by the image processing module, amount of each pathogen across the wound region.

~~18. The method as claimed in claim 16, the method comprising:~~

~~receiving, by the library database, a new set of standard spectral parameters identifiable with a new reference pathogen;~~

~~providing, by a model builder ensemble, a plurality of image processing models based on the new set of standard spectral parameters identifiable with the new reference pathogen and the set of standard spectral parameters identifiable with reference pathogen; and~~

~~fixing, by a cross-validator, a second image processing model from the plurality of image processing models, wherein the second image processing model is to replace a first image processing model, wherein the first image processing model is associated~~

~~with the set of standard spectral parameters and the second image processing model is associated with the set of standard spectral parameters and the new set of standard spectral parameters.~~