US Patent & Trademark Office
Patent Public Search | Text View

PHENOTYPE MEASUREMENT SYSTEMS AND METHODS

Abstract

An image acquisition and analysis system are disclosed. The system enables high throughput, objective analysis of microbial samples over days or weeks. The system may accommodate upwards of twelve 96- or 384-well plates simultaneously (liquid or solid media). The system may acquire and analyze a large number of samples in a short period of time. For example, over 384 samples per minute or 18,432 samples per hour. The system hardware may include a multi-spectral imager (fluorescence and bright field detection), electro-mechanical assemblies, and an optional high-resolution stage. The system may automate image acquisition, image data processing, simplify data storage, and enable automated analysis tools to significantly reduce the manual labor and time associated with such tasks. The system may allow for quick processing and analysis of data into clear phenotypic classes. The analysis capabilities may include colony growth, colorimetry, and structural morphology assays, and automated phenotype classification capabilities.

Related U.S. Application Data

Publication Classification

Background/Summary

TECHNICAL FIELD
[0002] This disclosure is generally related to the detection and analysis of phenotypes. More particularly, this disclosure is related to the automated detection, analysis, and classification of phenotypes of cellular assays.

BACKGROUND OF THE INVENTION
[0003] Current instrumentation for phenotype measurement is not keeping pace with the scale in which modern microbiology and cell molecular biology is performed. Quantitative methodologies are used to study cellular functions, the molecular mechanisms underlying specific phenotypes, and the levels of RNAs, proteins, and metabolites. For example, insights about the virulence or drug resistance of pathogenic bacteria or fungi could be gained from quantitative growth dynamics and morphological analyses of cellular colonies over extended periods of time (days to weeks). However, currently systems only provide for microbial researchers to choose between highly accurate temporal resolution experiments on a relatively small number of strains or conditions, or single end-point data acquisition for a large number of strains or conditions. Furthermore, current systems fail to provide an efficient means of integrating the vast quantities of data produced among a group of experiments or among the combined experiments of a group of collaborating researchers during data analysis.

SUMMARY OF THE INVENTION
[0004] An image acquisition and analysis system are disclosed. The system enables high throughput, objective analysis of two-dimensional or three-dimensional cell or colony cultures (including spheroid or organoid cultures) of animal, plant, or microbial samples over days or weeks. The system may accommodate upwards of twelve single-well plates, 96-well plates or 384-well plates simultaneously (liquid or solid media, including agar or other gel matrices). The system may acquire and analyzing a large number of samples in a short period of time. For example, over 384 samples per minute or 18,432 samples per hour. The system hardware may include a multi-spectral imager (fluorescence and bright field detection), electro-mechanical assemblies, system-level and sample-level environmental controls and monitoring, and an optional high-resolution

stage. The system may automate image acquisition, image data processing, simplify data storage, and enable automated analysis tools to significantly reduce the manual labor and time associated with such tasks. The system may allow for quick processing and analysis of data into clear phenotypic classes. The analysis capabilities may include colony growth, colorimetry, and structural morphology assays, and user-defined, supervised, or unsupervised automated phenotype classification capabilities.

[0005] In various aspects, the present disclosure provides methods and systems for the classification of one or more specimen. In some aspects, the present disclosure provides systems comprising a controller configured to interface with one or more instrument through an instrument gateway module configured to receive one or more experimental data set from the one or more instrument, wherein the one or more experimental data set is produced during one or more experiment extract one or more feature data set from the one or more experimental data set, store at least a portion of the one or more feature data set in a long-term data storage subsystem, store at least a portion of the one or more feature data set or at least a portion of the one or more experimental data set in a short-term storage cache, build one or more classification profile based on a classification data set comprising at least a portion of the one or more feature data set and classify one or more specimen of an experiment of the one or more experiment using the one or more classification profile.

[0006] In some aspects, the classification data set comprises at least a portion of each feature data set of a plurality of feature data sets, wherein a first portion of the each feature data set is produced from a first experimental data set and a second portion of the each feature data set is produced from a second experimental data set.

[0007] In some aspects of the present disclosure, the first experimental data set comprises data from a different experiment of the one or more experiment than the data of the second experimental data set. In some aspects, the controller receives a plurality of experimental data sets from a plurality of experiments before the extracting is performed on any of the experimental data sets. In some aspects, the controller receives a plurality of experimental data sets from a plurality of experiments before the classifying is performed on any of the experimental data sets. In some embodiments, at least a portion of the first experimental data set is received from a different instrument of the one or more instrument than the second experimental data set. In some respects, the classification of one or more specimen comprises categorizing the one or more specimen based on one or more feature data set. In some aspects, building the classification profile comprises supervised machine learning. In some aspects, building the classification profile comprises unsupervised machine learning. In some aspects, the classification is performed in real-time, near real-time, or batch mode.

[0008] In some aspects of the present disclosure, classification results are determined from the classification of one or more specimen of an experiment of the one or more experiment using the classification profile. In some aspects, the controller is further configured to display the classification results in real-time, near real-time, or batch mode. In some aspects, the controller is further configured to display an analysis data set comprising at least a portion of the experimental data set, at least a portion of the feature data set, or at least a portion of the classification data set. In some aspects, the analysis data set is displayed in real-time, near-real time, or batch mode.

[0009] In some embodiments of the present disclosure, the experimental data set comprises image data. In some embodiments, the experimental data set comprises a positive file format.

[0010] In some embodiments of the present disclosure, the controller is further configured to transmit an experiment design to the one or more instrument.

[0011] In some aspects of the present disclosure, the specimen comprises one or more cell. In some aspects, a cell of the one or more cell comprises a genetically modified cell. In some aspects, the specimen comprises a plurality of cells. In some aspects, the plurality of cells comprises a heterogeneous mixture of cells. In some aspects, the plurality of cells comprises one or more

colony of cells.

[0012] In some embodiments of the present disclosure, an experiment of the one or more experiments comprises an antibiotic screening assay, a drug screening assay, a cellular growth assay, a colony growth assay, a bio-prospecting assay, or an assay correlating molecular expression with functional activity.

[0013] In various aspects, the present disclosure provides methods for the classification of one or more specimen, the methods comprising: receiving one or more experimental data set from one or more instrument, wherein the one or more experimental data set is produced during one or more experiment; extracting one or more feature data set from the one or more experimental data set; storing at least a portion of the one or more feature data set in a long-term data storage subsystem; storing at least a portion of the one or more feature data set or at least a portion of the one or more experimental data set in a short-term storage cache; building one or more classification profile based on a classification data set comprising at least a portion of the one or more feature data set; and classifying one or more specimen of an experiment of the one or more experiment using the one or more classification profile.

[0014] In some aspects, a plurality of experimental data sets is received before the extracting is performed on any of the experimental data sets of the plurality of experimental data sets. In some aspects, a plurality of experimental data sets is received before the classifying is performed on any of the experimental data sets of the plurality of experimental data sets. In some aspects, the classification of one or more specimen comprises categorizing the one or more specimen based on one or more set of feature data. In some aspects, building the classification profile comprises supervised machine learning. In some aspects, building the classification profile comprises unsupervised machine learning. In some aspects, the present disclosure provides methods comprising displaying an analysis data set comprising at least a portion of the experimental data set, at least a portion of the feature data set, or at least a portion of the classification data set. In some respects, the classification results are displayed in real-time, near real-time, or batch mode. In some aspects, the present disclosure provides methods further comprising displaying an analysis data set comprising at least a portion of the experimental data set, at least a portion of the feature data set, or at least a portion of the classification data set. In some aspects, the present disclosure provides methods further comprising transmitting an experiment design to the one or more instrument.

INCORPORATION BY REFERENCE

[0015] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0017] FIG. **1** shows a block diagram of a system for integrated high-throughput phenotypic analysis of cellular assay data and associated data flow in accordance with one or more embodiments disclosed herein.

[0018] FIG. **2** shows a schematic diagram of a network for integrated high-throughput phenotypic analysis of cellular assay data in accordance with one or more embodiments disclosed herein.

[0019] FIG. **3** shows a flow diagram of a method for coordinating integrated high-throughput

acquisition and analysis of phenotypic cellular assay data in accordance with one or more embodiments disclosed herein.

[0020] FIG. **4** shows a flow diagram of a method for the integrated operation of an instrument in the high-throughput phenotypic analysis of cellular assay data in accordance with one or more embodiments disclosed herein.

[0021] FIG. **5** shows a flow diagram of a method for integrated high-throughput analysis of phenotypic cellular assay data in accordance with one or more embodiments disclosed herein.

[0022] FIG. **6** shows a flow diagram of a method for high-throughput analysis of phenotypic cellular assay data involving integration of an additional data acquisition tool in accordance with one or more embodiments disclosed herein.

[0023] FIG. **7** shows a flow diagram of a method for integrated high-throughput analysis of phenotypic assay data in accordance with one or more embodiments disclosed herein.

DETAILED DESCRIPTION OF THE INVENTION

[0024] The systems, methods, and devices described herein can be used to automatically and efficiently process experimental data from one or more experiment. In some embodiments, these systems, methods, and devices can be configured to coordinate and perform analysis and classification of massive data sets received from a plurality of data acquisition tools. For example, the systems, methods, and devices described herein can be used to automatically extract a customizable set of aspects or features from imaging data acquired from a plurality of high-throughput data acquisition tools, build an ontological classification profile based on features extracted from massive quantities of raw data, and apply the classification profile within or across data sets. Since a single instance of such analysis may use the functions or capabilities of a plurality of data acquisition tools (which can include one or more data processing system such as one or more computational tools), the systems, methods, and devices described herein may accomplish analysis and classification of a given data set by routing data to various modules, subsystems, or additional data acquisition tools.

[0025] The systems described herein may be used to analyze and/or classify data originating from image acquisition systems such as systems comprising a camera or a microscope. For example, the systems, methods, and devices described herein are well-suited for analysis of imaging data produced during growth and toxicity assays involving either prokaryotic or eukaryotic cells, including microbes (e.g., yeasts such as *Saccharomyces cerevisae*, bacteria such as *Escherichia coli*, or mutant variants thereof), mammalian cells, and other primary cells and cell lines (e.g., cell lines with or without artificially modified genetic material). For example, the systems, methods, and devices can be used to analyze data collected from cellular assays (e.g., colony growth or cellular toxicity assays involving yeast or bacteria) performed on liquid media substrates (e.g., liquid broth media such as YPD broth, wherein cellular specimens may be pooled) or solid media substrates (e.g., solid agar substrates). In some embodiments, data sets that can be analyzed or classified using the systems, methods, and devices described herein can be derived from a variety of assays and experiments, including antibiotic, biomarker, and drug screening assays, cellular growth assays, bio-prospecting assays (e.g., experiments pertaining to development of cellular strains for regenerative medicine, industrial biofuel production, agricultural microbial products and crop modifications, or environmental rehabilitation), molecular expression functional activity assays (colorimetric or fluorescent reporter molecules associated with enzyme, protein, RNA or metabolite production, such as antibody-linked reporters, genetically expressed reporters, or cell-permeable or non-cell-permeable dyes), morphologic behavior (structural assembly variation) and experiments pertaining to the identification and/or characterization of pathogenic or virulent cell types. Moreover, the systems, methods, and devices allow for analysis (e.g., feature extraction, classification, and/or comparison) of experimental data for individual experimental groups (e.g., a certain strain of yeast) across as many as 50, 100, 200, 500, 1000, 5000, 10000, or even 100000 experiments (e.g., analysis stacking), which may comprise an extremely large number of

experimental conditions in aggregate. In some embodiments, these analytical modalities can be repeated for each experimental group of a plurality of experimental groups, wherein the plurality of experimental groups can comprise 50, 100, 150, 200, 250, 500, 1000, 2500, 5000, 7500, or 10000 different specimens (e.g., cells comprising a different genetic modification or background).

[0026] The use of systems, methods, and devices described herein allows for identification of phenotypic and functional characteristics from analysis of samples (e.g., individual genetic variants) on a scale necessary for pharmacogenomic screening, quantitative trait mapping, synthetic biology, and systems biology approaches in both industrial and academic settings. For example, one or more complex trait (e.g., wherein multiple genes contribute to single phenotype) and/or one or more pleiotropic trait (e.g., wherein a single gene contributes to multiple phenotypes) can be identified or recognized in a specimen using the systems, methods, and devices described herein. In some embodiments, one or more correlation may be established between a set of experimental conditions (e.g., genetic strain of a cellular specimen or treatment conditions) and a set of one or more complex trait and/or one or more pleiotropic trait in a specimen. In some embodiments, advantages conferred by the capabilities of the systems and methods described herein (e.g., as a result of capacity for increased scale of experimental interrogation and data collection, highly controlled repeatability, high sampling rate, prolonged duration of data set collection, efficient data analysis, and/or statistical robustness resulting from cumulative accrual of analytical assets). These advantages allow for both analytical and predictive approaches to applications such as understanding associations between genotype and phenotype, mapping complex molecular pathways, understanding structural, chemical, and electrical cell-to-cell interactions in three-dimensional environments, and determining temporal expression patterns of RNA or proteins.

[0027] While described herein primarily in terms of analysis and classification of image-based data acquired from cell-based assays, it is contemplated that the systems, methods, and devices described herein can be used to analyze and classify virtually any data set. For example, the systems and methods described herein can be useful in the analysis (e.g., classification) of data sets produced or collected by non-imaging modalities (e.g., data from an electrochemical detection assay received from an instrument or **3**rd party tool). In some embodiments, analysis of non-image-based data (e.g., data or metadata received from an instrument, user, or **3**rd party tool) may be used to modify one or more data set used by the system for analysis (e.g., a feature data set, a training data set, or classification data set).

[0028] FIG. **1** shows an embodiment of system **100**, which can be useful in high-throughput phenotypic analysis of cellular assay data. System **100** can include a plurality of components in communication with one another, for example, via a local network connection or a telecommunication network connection (e.g., a telecommunication network in communication with platform system **101**). A component of system **100** can be a physical component (e.g., a user terminal **102** such as a computer or workstation, a data acquisition system **106**, **108**, a computational tool **104**, a router, a server, a processor, a controller, a data storage medium, or an automated device) or a virtual component (e.g., a software module **110**, **120**, **130**, **140**, **150** or software subsystem thereof). In some embodiments, one or more first component of system **100** can control one or more second component of system **100**, for example, through the transmission of instructions from the one or more first component to the one or more second component.

[0029] System **100** can comprise one or more user terminal **102**, and one or more data acquisition systems **106**, **108** (e.g., instrument **106**, **108**) or one or more computational tool **104**. User terminal **102** can comprise a computer, a mobile device, or a workstation. User terminal **102** can be connected to system **100** by connection **103**, which can be a wireless connection or a physical connection (e.g., a wired connection which may or may not involve wireless components, such as a wireless router). A data acquisition system can comprise an instrument **106**, **108** (e.g., a microscope, an experimental condition management system such as a fluidics system or culture plate management system, an environment control system such as an incubator, an imaging system

comprising a detector such as a camera and/or a source of radiation such as a laser or other illumination device).

[0030] One or more user terminal **102** may be connected to one or more additional user interface and/or to one or more data acquisition system by platform system **101**. One or more user interface terminal **102** may also be connected to one or more additional user interface and/or to one or more data acquisition system via a local network connection.

[0031] System **100** can include integrated modules for division and/or completion of individual tasks. System **100** can comprise a platform system **101** that can include, for example, an application module **110**, an instrument gateway module **120**, an analysis engine module **130**, an interface module **140**, and a storage module **150**. A subsystem or module of either system **100** or platform system **101** may be connected to one or more subsystem or module of either system **100** or platform system **101**, for example, to facilitate efficient analysis of stored or acquired experimental data. Application module **110** can provide services and tools related to the user interface for the system **100** for integrated high-throughput phenotypic analysis of cellular assay data. Application module **110** can receive one or more client request from the user (e.g., via connection **103**) and route or transmit the client request to one or more module or subsystem of system **100**. In some embodiments, the application module **110** can communicate information, such as settings, experimental results, analyzed data, and instructions for carrying out the high-throughput automated phenotypic analysis of the cellular assay data, between a system client (e.g., a user) and one or more module or subsystem of system **100**. For example, a system client may communicate an experiment design (e.g., input or transmit a client request) to experiment design subsystem **112** of application module **110** via a connection **103** using user terminal **102**. After being selected or defined by a client, an experimental design can be communicated to an instrument for execution (e.g., via instrument gateway module **120**) or to a subsystem comprising memory (e.g., storage module **150**) for future use.

[0032] Experiment design subsystem **112** can be configured to provide tools to a client useful in designing an assay (e.g., for execution by one or more data acquisition system **106, 108**). For instance, experiment design subsystem **112** can allow a client to define one or more aspect (e.g., one or more configuration parameter) of an experiment design, including one or more configuration parameter for one or more data acquisition system **108** (e.g., for communication to instrument gateway module **120**), one or more analysis method (e.g., for communication to analysis engine module **130**), one or more computational tool **104**, or one or more additional data acquisition tool **106** (e.g., for communication to interface module **140**).

[0033] A configuration parameter can be an experimental variable. In some embodiments, a configuration parameter can be an environmental condition or parameter, a treatment condition or parameter, a time parameter, a calibration parameter, an imaging method or condition, an image or data analysis method or algorithm, a detectable metric or feature, or a classification profile or method. For instance, a configuration parameter can be a number of experimental or control groups or replicates for an experiment, an experimental time point or endpoint, a statistical method, a threshold value (e.g., for image analysis, for statistical stringency, or for maintenance of environmental conditions), or a definition of one or more instruments to be used to carry out an experiment.

[0034] In some embodiments, a configuration parameter of an experiment design can comprise one or more custom (e.g., user-defined) configuration parameter, one or more pre-defined (e.g., stored) configuration parameter, or a combination of one or more custom configuration parameter and one or more pre-defined configuration parameter. A pre-defined configuration parameter may be defined by a configuration or software parameter of a data acquisition system, a configuration or parameter of stored data (e.g., a stored experimental design or classification profile). In some embodiments, a custom configuration parameter may be defined by, limited by, or informed by an aspect of a module or component with which the application module is in communication. For

example, a custom configuration parameter may be defined by or limited by the capabilities or preset parameters of an instrument or additional data acquisition tool selected for an experiment or by the set of configuration parameters of a selected stored experiment design (e.g., as communicated to application module **110** by storage module **150**), and it may be informed by actual environmental conditions detected in or around data acquisition system **106**, **108** (e.g., as communicated to application module **110** by instrument gateway module **120**).

[0035] Data visualization subsystem **114** can be configured to provide a user interface for viewing, interpreting, and visualizing the data and analysis results for an assay. Data visualization subsystem **114** can be used to present raw, partially processed, or fully processed data. Data presented to a client of system **100** can be qualitative or quantitative. Data visualization subsystem **114** can present data according to preset visualization profiles and functions or user-defined visualization preferences, which, in some embodiments, can each be selected prior to, during, or after the collection or presentation of experimental or analyzed data (e.g., by user input via connection **103**). Preset visualization profiles and functions and user-defined visualization preferences can be stored in storage module **150**. The format of data presented via data visualization subsystem **114** can comprise graphs, tables, charts, image stacks, three-dimensional renderings, movies (e.g., movie data captured as such by a data acquisition system or static images stitched together after collection), or a combination thereof.

[0036] In some embodiments, data can be presented via data visualization subsystem **114** in real-time or near real-time. For example, data produced, collected, or analyzed using a remote or local data acquisition system or using an additional data acquisition tool **106** or computational tool **104** can be transmitted to data visualization subsystem **114** (e.g., via one or more module or subsystem of system **100**) for immediate display. In some embodiments, data presented by data visualization subsystem **114** can be refreshed or updated without lag (e.g., in real-time) or with minimal lag (e.g., near real-time presentation, which can, in some embodiments, result from real-time data analysis performed by a module or subsystem of system **100**). In some embodiments, data can be presented in batch mode, which can comprise delaying the display of all or a portion of the collected or processed data (e.g., so that all or a portion of the data may be displayed at the same time). Batch mode presentation or analysis of data may be advantageous or necessary, for example, because it can allow for batch mode processing and can allow for low-cost processing and/or data storage availability.

[0037] Data presented via data visualization subsystem **114** can comprise experimental data (e.g., images captured during an experiment or partially processed images), analyzed experimental data (e.g., data resulting from quantitative or qualitative analysis of experimental data such as image data, feature data, graphs comprising raw data, processed data, or metadata), classification data (e.g., one or more classification profiles, one or more feature data set, and/or one or more experimental data set), classification results (e.g., as determined from classification of an experimental group or specimen), experimental condition data (e.g., measured environmental data such as temperature, humidity, barometric pressure, atmospheric gas composition, and camera or lighting settings), stored data, or metadata (such as time-based metrics like treatment or exposure durations and image capture intervals).

[0038] Data visualization subsystem **114** can be used to present imaging data recorded during an experiment. Imaging data can comprise individual sample or whole-plate images, time-lapse image series (e.g., images from an experiment edited together and presented with movie playback or slider bar controls). Imaging data can be raw, partially processed, or fully processed.

[0039] Raw or analyzed data can be passed to data visualization subsystem **114** from another module or subsystem of system **100**. For example, raw data can be transmitted from instrument gateway module **120** to data visualization subsystem **114**. In some embodiments, raw data can be passed from a subsystem of instrumentation gateway module **120**, such as image ingest subsystem **122** or instrument monitoring subsystem **126**. In some embodiments, data can be transmitted to

data visualization subsystem **114** from a subsystem of analysis engine module **130** (e.g., image processing subsystem **132**, feature extraction subsystem **134**, or classification subsystem **136**). Raw or analyzed data can also be passed to data visualization subsystem **114** from storage module **150**, and subsystems thereof. Data can be transmitted to the data visualization subsystem **114** from interface module **140** and subsystems thereof (e.g., after receipt from an additional data acquisition system **106**). In some embodiments, data from experiment monitoring subsystem **116** of application module **110** can be passed to data visualization subsystem **114**.

[0040] Application module **110** can comprise experiment monitoring subsystem **116**, which can be configured to provide status monitoring of the one or more data acquisition system **106**, **108** or computational tool **104**, during operation of the one or more data acquisition system (e.g., during data acquisition of a given assay). Experiment monitoring subsystem **116** can produce or comprise a means for producing a user interface for display of data or parameters relating to an experiment (e.g., a cellular assay).

[0041] For example, the status of a data acquisition system (e.g., an instrument **108** or an additional data acquisition tool **106**) or computational tool **104** may be passed to experiment monitoring subsystem **116** by instrument gateway module or a subsystem thereof. For example, a sensor of a data acquisition system (e.g., an instrument **108**) can detect or measure one or more aspect of an experiment or of data acquisition system **106**, **108** (e.g., one or more environmental condition, experimental parameter, time-based condition, analysis parameter, device status code, error code) and transmit the detected or measured data to experiment monitoring subsystem **116**. In some embodiments, experiment monitoring subsystem **116** can comprise a memory or storage cache into which data can be stored (e.g., a short-term storage cache or buffer for collection of experimental data to be displayed).

[0042] In some embodiments, data can be presented via experiment monitoring subsystem **116** in real-time or near real-time. For example, data collected or analyzed using a remote or local data acquisition system or using an additional data acquisition tool **106** or computational tool **104** can be transmitted to experiment monitoring subsystem **116** (e.g., via one or more module or subsystem of system **100**) for immediate display. In some embodiments, data presented by experiment monitoring subsystem **116** can be refreshed or updated without lag (e.g., in real-time) or with minimal lag (e.g., near real-time presentation, which can, in some embodiments, result from real-time data analysis performed by a module or subsystem of system **100**). Experiment monitoring subsystem **116** can also be operated in batch mode, which can comprise delaying the presentation of all or a portion of the collected or processed data (e.g., so that all or a portion of the data may be presented at the same time).

[0043] In some embodiments, experiment monitoring subsystem **116** may present a user with unrequested information and may, optionally, prompt the user for input (e.g., a client request). For example, if one or more status code or error message is received from one or more data acquisition system **106**, **108** or computational tool **104**, experiment monitoring subsystem **116** may present the one or more status code or error message to the user. In some embodiments, experiment monitoring subsystem **116** may present the user with a prompt to input preferences or commands (e.g., a client request) in response to the one or more status code or error message (e.g., to be transmitted to the one or more data acquisition system **106**, **108** or computational tool **104**). In some embodiments, a client request inputted by a user in response to a status code or error message may cause a modification or rectification of a status (e.g., an operational error of a data acquisition system **106**, **108** or computational tool **104** or an experimental parameter).

[0044] Instrumentation gateway module **120** can provide an interface to one or more instrument **108** and a means for communicating with the one or more instrument **108**. Instrument gateway module **120** can transmit data (e.g., instructions such as client requests) from one or more client (e.g., user terminal **102**, computational tool **104**, or data acquisition system **106**, **108**) to one or more instrument **108**. Data (e.g., experimental data) transmitted from instrument gateway module

120 to a computational tool **104**, or data acquisition system **106**, **108** can comprise experiment design information, setup or configuration instructions, status requests, instructions to initiate or terminate an operation (e.g., experiment initiation or termination instructions), or data originating from other modules, subsystems, instruments, or clients (e.g., an additional data acquisition tool **106** or computational tool **104**). Instrument gateway module **120** may also receive any type of data from an instrument, module, or subsystem of system **100**.

[0045] Instrument gateway module **120** and associated instruments and data acquisition computational tools can be configured to acquire very large experimental data sets. For example, testing of this system has shown that a high rate of sampling for collection of experimental data can yield unexpected levels of insight into the function and/or phenotype of a specimen (e.g., as a result of more precise dissection of temporal events and/or improved statistical resolution of subtle changes in quantifiable metrics); however, sampling at such a high rate can produce quantities of data that other systems and methods are not able to receive, analyze, classify, and/or store efficiently, if at all. In some embodiments, a high rate of sampling comprises sampling at less than the doubling rate of a cellular specimen, less than half the doubling rate of a cellular specimen, less than one third the doubling rate of a cellular specimen, less than one quarter the doubling rate of a cellular specimen, or less than one eight the doubling rate of a cellular specimen (e.g., when doubling rate is measured in a log phase of cellular growth). In some embodiments, the doubling rate of a microbial species (e.g., bacteria, fungi, like yeast) can range from 10 minutes to 45 minutes, from 15 minutes to 30 minutes, from 20 minutes to 25 minutes, from 45 minutes to 60 minutes, from 60 minutes to 90 minutes, from 90 minutes to 180 minutes, from 90 minutes to 140 minutes, or from 105 minutes to 120 minutes.

[0046] In some embodiments, instrument gateway module **120** may automatically transmit (e.g., without requiring user input) data received from another module or client to one or more data acquisition system **106**, **108** or computational tool **104**. For example, during execution of an experimental design requiring the coordinated function of two or more instruments, modules, and/or additional data acquisition tools, instrument gateway module **120** may send data received from a first instrument or module of system **100** to a second instrument or module of system **100** automatically. In some embodiments, data acquired from instrumentation gateway module **120** can comprise an image ingest subsystem **122**. Image ingest subsystem **122** may be configured to accept data (e.g., experimental data) captured by one or more data acquisition system **106**, **108** during operation (e.g., during execution of an assay of an experiment). In some embodiments, data received by image ingest subsystem **122** may include, but is not limited to, images of plated cellular samples, environmental data (e.g., parameters such as temperature, percent gas composition, and humidity), instrument settings (such as shutter speed, focal point, and duration of exposure) and sample traceability data (such as barcoding, QR codes, or RFID), and sample plate calibration information (e.g., data relating to one or more of a dimension, feature, hue, saturation, contrast, intensity, or other colorimetry parameters of a sample). Image data passed to image ingest subsystem **122** can be individual static images, grouped static images (e.g., image stacks), or movie files.

[0047] Instrumentation gateway module **120** can comprise instrument setup subsystem **124**, which can be configured to receive experimental data comprising one or more configuration parameter. Instrument setup system **124** can be configured to transmit a client request to data acquisition system **106**, **108** or computational tool **104** and/or to receive one or more configuration parameter for an assay (e.g., one or more parameter of an experiment design) from data acquisition system **106**, **108**. In some embodiments, a configuration parameter may be a capture interval, a plate configuration, a number of samples (e.g. a number culture plates or biological samples on a culture plate), an identification number (e.g., of an experiment or portion of an experiment such as a plate or region of a plate), an imaging parameter (e.g., a setting related to a filter or image filtering method, a setting related to an illumination source, a setting related to signal detection such as

selection of a detection method or specification of a gain level, intensity threshold, or contrast threshold), a start time, or a duration (e.g., a duration of an experiment or capture event such as shutter speed of an imaging event). In some embodiments, data may be received by image setup subsystem **124** from experiment design subsystem **112** and transmitted to instrument **108**.

[0048] Instrumentation gateway module **120** can also comprise instrument monitoring subsystem **126**. Instrument monitoring subsystem **126** can be configured to receive the instrument status data from one or more instrument **108**. Instrument status data, which can comprise experimental data, can be transmitted from instrument monitoring subsystem **126** to another module or subsystem of system **100**. For example, instrument monitoring subsystem **126** may pass instrument status data from one or more instrument **108** to experiment monitoring subsystem **116**. In some embodiments, data transmitted or received by instrument monitoring subsystem **126** can comprise instrument user/operator logs, experiment runtime logs, error logs, temporal environmental condition data (e.g., relating to internal conditions of one or more instrument **108**), service history, hardware configuration information, and software configuration information.

[0049] Analysis engine module **130** can be configured to perform analysis of experimental data produced, stored, or received by one or more component of system **100**. For example, analysis engine module can be used to automatically perform phenotypic classification of cellular samples of an assay. In some embodiments, analysis engine module or a subsystem thereof may use data created or received by system **100** (e.g., experimental data such as raw image data as well as or instead of feature data extracted from experimental data) to build a new classification profile or to revise an existing classification profile. Analysis engine module **130** or a subsystem thereof may also apply a classification profile (e.g., a stored classification profile or a newly created classification profile) to a data set (e.g., in order to classify one or more experimental group, such as one or more specimen of an experiment). Data useful for creation or revision of a classification profile can be raw data, partially processed data, or fully processed data. In some embodiments data used by analysis engine module **130** can be extracted feature data and can comprise a feature data set.

[0050] Analysis engine module **130** can comprise image processing subsystem **132**, which can be configured to pre-process images in preparation for feature extraction. Image processing subsystem **132** can apply one or more image processing method to an input image stream received, for example, from one or more of the instrument **106**, **108**. An image processing method can be defined by and passed to analysis engine module **130** from storage module **150**, a computational tool **104**, an additional data acquisition tool **106**, or a user input (e.g., via a user terminal **102**).

[0051] Image processing subsystem **132** can be configured to identify aspects of an image (e.g., image features) and can, in some embodiments, apply one or more modification to one or more image of the input image stream, such as filtering, thresholding, gray-scaling, Gaussian blur. In this way, partial processing of one or more image of an image stream collected by an instrument **106**, **108** can be accomplished by image processing subsystem **132**. Whether pre-processing is performed by image processing subsystem **132** and the combination and, if so, the degree to which processing methods are applied by image processing subsystem **132** can comprise a client request (e.g., comprising an experimental design) passed to analysis engine module **130** from application module **110** or an aspect of an experimental design stored in storage module **150** and selected by a user or used as a default method for a certain experimental design. Image processing subsystem **132** can transmit one or more raw or partially processed image of an image stream to feature extraction subsystem **134**. In some embodiments, a partially processed image can comprise data in a positive file format, such as TIFF or JPEG formatting.

[0052] In some embodiments, image processing subsystem **132** can receive and process a raw image sensor file (e.g., from an instrument **106**, **108** or from storage module **150**) or an image previously converted to a positive file format (e.g., by instrument **106**, **108**, or by another module, subsystem, or component of system **100**). For example, image processing subsystem **132** can

convert a raw image sensor file (e.g., raw image data) to a positive file format such as TIFF or JPEG before passing the data to another subsystem of the analysis engine module, such as feature extraction subsystem **134**.

[0053] Feature extraction subsystem **134** can be configured to receive and process the data output of the image processing subsystem **132**. For example, feature extraction subsystem **134** can receive one or more image of an image stream from image processing subsystem **132** and can be used to extract one or more feature from the one or more image. In some embodiments, feature extraction subsystem **134** can be used to measure image features of a cellular sample. Feature data that can be extracted from collected and/or processed data (e.g., experimental data, such as image data) can comprise one or more quantitative or qualitative aspect of an image. In some embodiments, a feature data set may comprise both one or more quantitative aspect of an image and one or more qualitative aspect of an image.

[0054] Feature data (e.g., image feature data) extracted by feature extraction subsystem **134** may include, but are not limited to, object detection, object counting, circularity, statistical measurements of intensity and color channel (e.g., absolute intensity, hue, and/or saturation measurement or measurement of spatial changes in intensity, hue, and/or saturation), edge detection, segmentation and segment counting, and/or dimensional measurement (e.g., length, thickness, area or diameter measurement). In some cases, feature data may be extracted based whether the data meets or exceeds one or more threshold value. In some embodiments, feature data may comprise one or more feature determined or calculated from one or more other feature data set (e.g., a relative measurement). For example, an object's height may be calculated from one or more measurement of intensity and/or data comprising a position of the focal plane of the image. In some embodiments, feature extraction subsystem **134** may comprise a method for identifying or quantifying a centroid of a cell or group of cells (e.g., a colony of cells, which can comprise a plurality of cells that are physically associated or unassociated with one another), relative position of an object or group of objects (e.g., with respect to the same object in a time course or with respect to a second object, such as a cell, or group of objects, such as a colony of cells, at a given time point or over a time course), a method of using regions of interest (ROIs) or masked image data to determine a boundary of an object (e.g., for determining differences in cell or colony position or size) or group of cells (e.g., a colony of cells), a method of determining the one or more dimension or quality of a portion of an image (e.g., a determination of the length and/or thickness of a cellular filament or portion thereof), or a method of texture segmentation (e.g., a method of determining cellular edge ruffling, halo features of a cell or colony, or ridged features of a cell or colony).

[0055] Feature data can also comprise data determined or calculated by comparing a plurality of data sets. In some embodiments, feature data can be calculated or otherwise determined by comparing two or more individual frames of a video and/or two or more images in a temporal sequence of images, such as a time lapse image set. For example, colony growth rate can be determined by measuring and comparing a colony diameter in two or more images of an experimental data set.

[0056] Feature extraction subsystem **134** can transmit processed (e.g., partially processed or fully processed) image data and/or extracted feature data from images of an image stream to the classification subsystem **136**. In some embodiments, feature extraction subsystem **134** can send data, which may include one or more extracted feature of one or more image of the image stream, to the classification subsystem **136** without sending the images themselves.

[0057] Analysis engine module **130** can comprise classification subsystem **136** for classification of one or more data set and/or one or more experimental group (e.g., one or more specimen of an experiment) based on raw, partially processed, and/or fully processed data (e.g., raw image files, extracted features, and/or data produced by additional data acquisition tools). Classification of one or more data set and/or one or more experimental group (e.g., one or more specimen, such as a cell

type) can involve assigning a functional or phenotypic label or categorization to the data set or experimental group or categorizing the data set or experimental group based on a functional or phenotypic trait of the data set or experimental group (e.g., as determined by a comparison of the data set or a data set related to the experimental group to one or more additional data set, such as a data set related to a different experimental group). Classification of one or more data set and/or one or more experimental group can comprise applying a classification profile to a data set of an experiment or the compiled or aggregated data from a plurality of data sets or experiments. In some embodiments, classification subsystem **136** can comprise grouping data sets or experimental groups by a functional or phenotypic parameter (e.g., as determined from classification of experimental data). In some embodiments, classification subsystem **136** can comprise a memory or storage cache into which data can be stored (e.g., a short-term storage cache or buffer for collection of experimental data to be displayed).

[0058] A classification profile can be built (e.g., created, compiled, revised, or modified) by comparing two or more data sets in which a relationship between at least one aspect of each data set and at least one functional or phenotypic aspect of the data set is known (e.g., in order to better define the parameters governing the relationship between the at least one aspect of the data set and the at least one functional or phenotypic aspect of the data set). In some embodiments, a classification profile can be built by analysis engine module **130** or a subsystem thereof (e.g., classification subsystem **136**) using a machine learning algorithm. In some embodiments, a classification profile can be built using a labeled training data set (e.g., supervised classification), and, in some embodiments, a classification profile can be built without using a labeled training data set (e.g., unsupervised classification). A labeled training data set can comprise a sample data set (e.g., comprising experimental data, calculated data, and/or data from another source such as one or more scientific literature source) that bears an indication of a feature, function, phenotype, classification, or other categorization represented by at least a portion of the labeled training data set. In some embodiments, a classification profile can be an interrogation filter. In some embodiments, a classification profile can be inputted by a client of system **100** (e.g., via application module **110** or interface module **140**) and may be stored in a module or subsystem of system **100** (e.g., storage module **150** or classification subsystem **136**).

[0059] Classification subsystem **136** may apply a method of classification to a data set (e.g., a data set comprising one or more feature data set), depending, for example, on the configuration of the assay from which the data being analyzed is derived. A method of classification can comprise a supervised method of classification or an unsupervised method of classification. A method of classification (e.g., a method of applying a classification profile to a data set) can comprise dimensionality reduction, one or more Monte Carlo-based technique (e.g., Monte Carlo random sampling, Markov chain Monte Carlo, or Monte Carlo feature selection), clustering and anomaly detection, regression modeling, principal component analysis, linear discriminant analysis, binary, multi-class and linear classification based on labeled training data.

[0060] In some embodiments, a validation technique can be used to validate a classification result. For example, cross-validation using standard measures such as accuracy and precision may be employed for validation of a classification result.

[0061] In some embodiments, classification subsystem **136** may use one or more aspect of a data set (e.g., one or more raw image or portion thereof and/or one or more extracted feature such as a distance, a diameter, or an image contrast and complexity assessment) to determine one or more phenotypic or functional characteristic of the data set or of one or more parameter producing the data set (e.g., an experimental group, such as a cell type). In some embodiments, one or more relationship between an aspect of a data set and a phenotypic or functional characteristic (e.g., as determined by classification subsystem **136**) can be stored in a memory-containing module of system **100** (e.g., a short-term storage cache or a long-term data subsystem of one or more of storage module **150**, analysis engine module **130**, or classification subsystem **136**). In some

embodiments, one or more relationship between an aspect of a data set and a phenotypic or functional characteristic can be compiled into a classification profile, which can be stored in a module or subsystem of system **100** comprising memory.

[0062] In some embodiments, classification subsystem **136** may perform predictive classification of data as it is received by a module or subsystem of system **100**. In some embodiments, predictive classification can be performed in real-time or near real-time as data is received by classification subsystem **136**. Predictive classification can comprise the use of machine learning methods or algorithms.

[0063] Classification subsystem **136** can be configured to receive data from image processing subsystem **132**, feature extraction subsystem **134**, storage module **150**, or a combination thereof, in conjunction with other data points gathered or used by instruments **106**, **108**, application module **110**, interface module **140**, or instrumentation gateway module **120**. In some embodiments, data used by classification subsystem **136** can comprise metadata, experiment design information, or configuration parameters.

[0064] Interface module **140**, which may be a software-as-a-service (Saas) API Layer, can be configured to provide a web services interface (e.g., a REST API) and/or one or more software development kit for one or more software application or instrument to access, control, and interact with the rest of the system **100**. For example, may comprise a portal for transmission of a client request (e.g., an experiment design or portion thereof or instructions to execute an experiment design) to a remote additional data acquisition tool. In some embodiments, interface module **140** can comprise a software development kit useful in creating software to be used in interfacing with a computational tool **104** or an additional data acquisition tool **106** with system **100**.

[0065] Interface module **140** can comprise image ingest API subsystem **142**, which can be configured to provide for the integration of instrumentation or tools to access the image ingest subsystem **122**. In some embodiments, image ingest API subsystem **142** can receive data (e.g., experimental data such as image data, extracted feature data, metadata, or data related to a classification profile or protocol) into system **100**. For example, rules or routines comprising image ingest API subsystem **142** may be used in the receiving of imaging data from an additional data acquisition tool **106** (e.g., an instrument **106**) and subsequently transmitting the data to image ingest subsystem **122** (e.g., for further analysis or storage in one or more module or subsystem of system **100**). In some embodiments, software or firmware may be received by platform system **101** from one or more additional data acquisition tool **106** or computational tool **104** via image ingest API subsystem **142**.

[0066] Interface module **140** can comprise analysis API subsystem **144**, which can be configured to provide a means of integrating one or more computational tool **104** and/or one or more additional data acquisition tool **106** with analysis module **130** (e.g., feature extraction subsystem **134** and/or classification subsystem **136**). In some embodiments, analysis API subsystem **144** can transmit data received from one or more computational tool **104** or additional data acquisition tool **106** (e.g., via image ingest API subsystem **142**) to another module or subsystem of system **100**. For example, analysis API subsystem **144** can communicate data created or processed by computational tool **104** or by an additional data acquisition tool **106** and received by image ingest API subsystem **142** to image processing subsystem **132**, feature extraction subsystem **134**, or classification subsystem **136**.

[0067] Interface module **140** can also comprise storage API subsystem **146**, which can be configured to communicate data from storage module **150** to one or more computational tool **104** or additional data acquisition tool **106**, or vice versa. For example, data produced by a computational tool **104** or an additional data acquisition tool **106** may be downloaded to system **100** via storage API subsystem **146**. In some embodiments, stored data may be exported to one or more computational tool **104** or one or more additional data acquisition tool **106** via storage API subsystem **146**. For example, experiment design or experiment metadata may be received from

experiment definition subsystem **152** or experiment metadata subsystem **154**, respectively, and transmitted to one or more computational tool **104** or one or more additional data acquisition tool **106** (e.g., in order for an experiment to be carried out using one or more additional data acquisition tool). In some embodiments, data used by one or more computational tool **104** or one or more additional data acquisition tool **106** may be transmitted from storage module **150** (or a subsystem thereof, such as long-term image store subsystem **158**) via storage API subsystem **146**.

[0068] In some embodiments, a plurality of subsystems of interface module **140** may be used to communicate data between system **100** and one or more computational tool **104** or one or more additional data acquisition tool **106** for the purpose of data analysis and/or classification. For example, analysis API subsystem **144** and/or storage API subsystem **146** may be used to access image processing methods or algorithm libraries, visualization tools, or sample metadata for data classification.

[0069] In some embodiments, a plurality of subsystems of interface module **140** may be used to communicate data (e.g., download data to system **100** or export data to one or more computational tool **104** or one or more additional data acquisition tool **106**) for the purpose of allowing a computational tool **104** or an additional data acquisition tool **106** to access the data, methods, algorithms, functions, or protocols of one or more module or subsystem of system **100**. For example, an additional data acquisition tool **106** may transmit image data to system **100** via image ingest API subsystem **142** to be transmitted to analysis engine module **130** by analysis API subsystem **144** for analysis and subsequent export through interface module **140** or data storage in storage module **150**.

[0070] Storage module **150** can comprise subsystems and methods for persistent storage and data management. Storage module **150** and subsystems thereof may receive data directly from or transmit data directly to any other module of system **100**. Data stored in storage module **150** can comprise raw data, partially processed data, or fully processed data. For example, data stored in storage module **150** can include raw image data, extracted feature data, classification profile data, metadata, experiment design data, user profile or login data, interface data, or any other type of data described or implied herein.

[0071] Storage module **150** may include experiment definition subsystem **152**, which can be configured to maintain the data associated with the execution of experimental assays and protocols. Experiment definition subsystem **152** may be used to store pre-defined methods and protocols for one or more assay, which can comprise an experiment design. Experiment definition subsystem **152** can also comprise custom (e.g., user defined) methods and protocols for one or more assay, which can also comprise an experimental design. Data stored in experiment definition subsystem **152** can be transmitted to instrument gateway module **120** or interface module **140** to define settings and/or to control or instruct one or more data acquisition system **106**, **108** or computational tool **104** or communications therewith.

[0072] Storage module **150** can comprise experiment metadata subsystem **154**, which can maintain intermediate and final data (e.g., partially or fully processed data) received from analysis module **130**. Data stored in experiment metadata subsystem **154** can be transmitted to other modules and subsystems of system **100** in order to fulfill various functions. For example, data stored in experiment metadata subsystem **154** can be transmitted to classification subsystem **136** for data classification or to data visualization subsystem **114** for display. In some embodiments, data stored in experiment metadata subsystem **154** can be made available to one or more computational tool **104** or one or more additional data acquisition tool **106** via interface module **140** (e.g., for further data processing).

[0073] Image cache subsystem **156** of storage module **150** can comprise memory for maintaining data (e.g., image data) received from one or more data acquisition system **106**, **108**. In some embodiments, data maintained by image cache subsystem **156** can be transmitted to analysis module **130** for processing or classification. The image cache subsystem **156** may maintain the

image data at a quality suitable for visualization by the application module **110**. In some embodiments, data in image cache subsystem **156** can be maintained in more than one availability state, wherein an availability state can comprise image data having formatting or resolution conducive to instant, near-instant, or delayed processing, analysis, or visualization. In some embodiments, it is possible to more efficiently supply image data to one or more other module or subsystem of system **100** by maintaining image data in a plurality of availability states, depending on whether batch, near-real-time, or real-time processing, analysis, or visualization is used for a given client request or system function, which can, in turn, be determined at least in part by processing cost and/or storage availability.

[0074] Long term image store subsystem **158** of storage module **150** can be configured to maintain (e.g., store) image data acquired by data acquisition platform **106**, **108** at a quality suitable for processing in an archived format (e.g., for long-term and/or low-cost storage).

[0075] Instrument cache subsystem **159** of storage module **150** can be configured to maintain data and information associated with a data acquisition system interface, such as an instrument configuration. Data received from instrument gateway module **120** or a subsystem thereof, which can include any processed or utilized by instrument setup subsystem **124** or instrument monitoring subsystem **126**, can be stored in instrument cache subsystem **159**. Data stored in storage module **150** or a subsystem thereof (e.g., instrument cache subsystem **159**) can be transmitted by storage module **150** or the subsystem thereof to analysis engine module **130** or a subsystem thereof (e.g., image processing subsystem **132**, feature extraction subsystem **134**, or classification subsystem **136**) for analysis, which can include classification.

[0076] Referring now to FIG. **2**, system **200** can comprise a plurality of connections to a plurality of clients, where a client can comprise a device of system **200**. Clients connected to integrated platform **201** can include individual user terminals, locally networked user terminals, individual instruments, locally networked instruments, additional data acquisition tools, and additional data processing tools such as computational tools. In some embodiments, a first and second instrument **106**, **108** may be a first plurality of instruments and a second plurality of instruments, respectively. In some embodiments, system **200** can be an embodiment of system **100**, and integrated platform **201** can be an embodiment of platform system **101**. Integrated platform **201** (and, thus, platform system **101** as well) may comprise one or more server **202**, one or more memory **204**, and one or more processor **206** or controller. Modules, subsystems, or any function thereof may be coordinated, controlled, or executed by a controller or processor **206**.

[0077] In some embodiments, a first portion of platform system **101** or integrated platform **201** (e.g., a first group comprising one or more module or subsystem as described herein) can be executed in a different computing environment than a second portion of platform system **101** or integrated platform **201** (e.g., a second group comprising one or more module or subsystem, as described herein). A computing environment for executing the functions of a first or second portion of platform system **101** or integrated platform **201** may comprise a client of system **100** or system **200**. For example, a first portion of data used in the systems and methods described herein (e.g., experimental data, feature data, metadata, classification data, classification profile(s), classification results, image data, partially-or fully-processed data, or stored data) can reside permanently or temporarily in a different computing environment than a second portion of data used in the systems or methods described herein. In some embodiments, an encryption key may be employed by the computing environment or may be assigned to a portion of the data itself (e.g., cumulative cryptographic hashes).

[0078] A client (e.g., a user terminal **102**, computational tool **104**, or a data acquisition system **106**, **108**) may be connected directly to a module of integrated platform **201** (e.g., application module **110** or interface module **140**), to one or more additional client (e.g., either locally or remotely). In some embodiments, a client can be connected to integrated platform **201** directly and to one or more additional client through the connection each client shares with integrated platform **201**. In

some embodiments, the access to one or more additional client granted to a first client can be determined by a module or subsystem of integrated platform **201**. In some embodiments, such access can be granted to a first client for a limited period of time. In some embodiments, such access can be granted for compensation, such as a fee or mutual access granted to the one or more additional client. In some embodiments, a client can be assigned to a workgroup according to the customer and/or function with which the client is associated. A workgroup of system **200** can comprise one or more client. For example, a workgroup can comprise one or more user terminal **102** and/or one or more data acquisition system (e.g., one or more instrument and/or one or more additional data acquisition tool).

[0079] An instrument of system **100** can comprise any means of performing, measuring, detecting, or quantifying an aspect of an experiment or assay. For example, system **100** can comprise one or more instrument **106**, **108**, which can be a portion of a data acquisition system or an additional data acquisition tool. In some embodiments, instrument **106**, **108** can comprise an image capture system, which can comprise one or more infrared light, visible light, fluorescent light or ultraviolet light detector (e.g., a photomultiplier tube or camera such as a digital camera capable of recording still images or video images), or a microscope. An instrument **106**, **108** can also comprise a light source (e.g., an ultraviolet light source, an infrared light source, a laser light source, or a visible light source, which can comprise one or more configuration for enhancing contrast such as phase contrast, differential interference contrast, bright field, dark field, Hoffman modulation, or polarized light techniques) or a source of electrical or magnetic stimulation. In some embodiments, an instrument **106**, **108** can comprise a mechanism for moving all or a portion of an image capture system, such as a motor, a two-dimensional or three-dimensional gantry, and/or a lens focusing system. An imaging system can be operated according to an imaging method, which can be, can depend upon, or can be limited by an experiment design.

[0080] In some embodiments, an imaging system of instrument **106**, **108**, such as a motorized camera system, can be automated. For example, the imaging method with which or order in which one or more sample (e.g., one or more plate comprising one or more specimen or colony of specimens) is assayed (e.g., imaged) can be automatically determined and/or controlled by one or more module or subsystem of system **100**.

[0081] In some embodiments, instrument **106**, **108** can comprise or be operated in a controlled environment. For example, instrument **106**, **108** can comprise one or more of a temperature gauge (e.g., a thermometer), a humidification mechanism (e.g., a humidity pan, a humidification chamber, or a microhumidifier), a humidity sensor, a source of a gas (e.g., carbon dioxide, oxygen, nitrogen, methane or any combination thereof such as 5%, 10%, or 50% carbon dioxide in nitrogen, 5% or 10% carbon dioxide and 5% or 10% oxygen in nitrogen, or 10% oxygen in nitrogen), a gas concentration measurement system (e.g., a gas analyzer), or a heating source (e.g., an electrical heat source or water-insulated heating jacket). In some embodiments, instrument **106**, **108** can comprise a spectroscope (e.g., ultraviolet-visible spectroscope, near-infrared spectroscope, X-ray chromatography equipment, atomic emission chromatography equipment, or a mass spectrometer such as LC-MS-MS), gas chromatography system, or a liquid chromatography system (such as high-performance liquid chromatography). In some embodiments, an instrument can comprise an environment at 0, 1, 2, 3, 4, 5, 6, 10, 15, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 45, 50, 55, 60, 65, 70, 71, 72, 75, 80, 85, 90, 95, or 100 degrees Celsius, and an experiment or assay, as described herein, can be performed at 0, 1, 2, 3, 4, 5, 6, 10, 15, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 45, 50, 55, 60, 65, 70, 71, 72, 75, 80, 85, 90, 95, or 100 degrees Celsius. For example, microbial growth assays can be performed at 37 degrees Celsius.

[0082] Instrument **106**, **108** can also comprise a system for moving a sample before, during, or after an experiment. For example, instrument **106**, **108** can comprise a sample handling system, which can comprise a culture plate management system and/or a fluidic system. A plate

management system can comprise a plurality of culture plates or trays, which can each comprise 1, 2, 3, 4, 6, 12, 24, 48, 96, or 384 wells. In some embodiments, a plate management system can comprise a tray or plate stacker, a tray or plate selector, a tray or plate positioner, and/or a moveable microscope stage. In some embodiments, an instrument **106**, **108** can be capable of capturing image data from at least one, at least two, at least three, at least four, at least five, at least six, at least seven, at least eight, at least nine, at least ten, at least eleven, or at least twelve single-well plates, 96-well plates or 384-well plates simultaneously.

[0083] In some embodiments, a sample management system of instrument **106**, **108**, such as a plate management system, can be automated. For example, the order in which one or more sample (e.g., one or more plate comprising one or more specimen or colony of specimens) is assayed (e.g., imaged) can be automatically determined and/or controlled by one or more module or subsystem of system **100**.

[0084] In some embodiments, one or more aspect of instrument **106**, **108** can be controlled by a module or subsystem of system **100**. In some embodiments, one or more aspect of instrument **106**, **108** can be operated automatically. One or more instrument **106**, **108** of system **100** can be operated locally or remotely using instructions received from platform system **101**. In some embodiments, a user can specify one or more measurement, statistical comparison, assay, experiment, or series of experiments to be performed using one or more specimen, and platform system **101** can automatically partition tasks, select equipment (e.g., one or more instrument **106, 108** based on instrument availability and/or capability) to perform the tasks, transmit instructions (e.g., an experiment design) to one or more instrument for obtaining the user-requested one or more measurement, comparison, assay, experiment, or series of experiments.

[0085] In some embodiments, system **100** can comprise one or more computational tool **104** or one or more additional data acquisition tool **106** with which system **100** communicates through an interface module. In some embodiments, an additional data acquisition tool can comprise an instrument **106** (e.g., additional data acquisition tool **106**). In some embodiments, additional data acquisition tool can comprise a data processing tool (e.g., a computational tool **104** or computational platform). A data processing tool, which can, for example, comprise a computational tool **104**, can comprise an analysis platform, such as a computational biology platform. In some embodiments, data transmitted to instrument **106** or data processing tool (e.g., computational tool **104**) can undergo analysis (e.g., partially or fully processing or classification). Optionally, data analyzed by an instrument **106** or computational tool **104** can be received by platform system **101** (e.g., a subsystem of interface module **140**) after analysis by the instrument or data processing tool. For example, one or more experimental data set, feature data set, and/or classification data set can be transmitted to a computational tool **104** where it can be analyzed and/or where computational tool **104** may build a classification profile, which can be received from computational tool **104** by interface module **140** or a subsystem thereof.

[0086] Referring now to FIG. **3**, process **300** represents an example of how a client (such as a user at a user terminal **102**) may access all functionalities of system **100**, as described herein. For instance, system **100** may receive and may validate login information from the client in a step **302**. In some embodiments, a client can be a local area network account, which can be connected to one or more user terminal **102**, one or more computational tool **104**, and/or one or more data acquisition system **106**. The client can be synchronized with a server of system **100** in a step **304**. Synchronization of a client with a server of system **100** may comprise transmitting and/or receiving updated data, software, or firmware from the client to the platform system **101**. In a step **306**, the client may be assigned to a workgroup, which may or may not comprise one or more additional client. If the workgroup to which the client is associated also comprises one or more additional client, the client may be synchronized with all or a portion of the additional client(s) in the workgroup via system **100** in a step **308**. In some embodiments, a workgroup can comprise one or more of a user terminal, a data acquisition system **108**, a computational tool **104**, and/or additional

data acquisition system **106**. A first client of a workgroup may be local or remote with respect to a second client of a workgroup and may or may not allow access to the second client of the workgroup (e.g., for the purpose of sharing data, experimental resources, or computational resources) and may or may not require compensation for said access.

[0087] After the client has been assigned to a workgroup and optionally synchronized with one or more additional client of the workgroup, data may be presented to the client in a step **310** reflecting update information pertaining to input options, ongoing or completed experiments, or stored data (e.g., via any of the subsystems of application module **110**). At step **320**, the client may input a client request to application module **110**, which can be transmitted to instrument gateway module **120** (e.g., in a step **340**), analysis module **130** (e.g., as in a step **350**), interface module **140** (as in a step **360**), and/or storage module **150** (e.g., as in a step **330**). A client request can comprise one or more command (e.g., instructions to display at least a portion of a data set, instructions to operate a data acquisition system, instructions to create, edit, or delete data or to retrieve data from long-term or short-term storage, or instructions to perform one or more method of data analysis such as applying one or more classification profile to a data set) or one or more data set (e.g., wherein a data set can comprise experimental data, feature data, classification data, one or more classification profile, metadata, one or more aspect of an experimental design, or training set data). Commands (e.g., instructions) contained in the client request can be carried out by the modules and subsystems of system **100** automatically. For example, a client request may specify a plurality of assays be performed on a plurality of specimens and that one or more feature data set be extracted from the resulting experimental data set before one or more classification profiles is applied to the feature data set and that classification results be displayed in real-time, and platform system **101** can automatically task one or more data acquisition systems (e.g., via instrument gateway module **120** or via interface module **140**, as in steps **340** and **360**, respectively), request previously stored classification data be transmitted from storage module **150** to analysis engine module **130** (e.g., as in a step **330**), and/or instruct analysis engine module **130** to execute one or more feature extraction or classification method on data received in analysis engine module **130** from instrument gateway module **120** or interface module **140** (e.g., as in a step **350**). At step **332**, **342**, **352**, and **362**, data may be returned (e.g., received) from the instrumentation gateway module **120**, analysis module **130**, interface module **140**, and/or storage module **150** for display via application module **110** (e.g., in batch mode display, in near-real-time display, or in real-time display). The system can accept additional client requests prior to, during, or after display of returned data in step **310**.

[0088] In some cases, client requests may be stacked. For example, a plurality of client requests, which may or may not be interrelated with respect to data set, experiment, or data acquisition system, can be inputted by a user (e.g., via application module **110**) and stored in a short-term or long-term memory of system **100** (e.g., in storage module **150**, a memory of instrument gateway module **120**, a memory of analysis engine module **130**, a memory of interface module **140**, or a memory of a client, such as a user terminal or data acquisition system). In some embodiments, system **100** may transmit or execute a client request from a plurality of different clients at the same time. For example, system **100** may transmit client requests from a plurality of clients to the single instrument to be executed together or sequentially (e.g., if the client requests each comprise one or more similar aspect such as a similar experiment design), regardless of when the client requests were received from the client, whether the client requests pertain to the same experiment, or whether the client requests will produce or use the same data set(s) in when the data set(s) are collected/produced, analyzed, or displayed. By regulating and grouping or batching a plurality of client requests or one or more portion of a plurality of client requests, it is possible to increase computational efficiency and efficiency of data acquisition system usage.

[0089] Turning now to FIG. **4**, process **400** represents embodiments of the operation of system **100** wherein an instrument (e.g., a data acquisition system) is utilized in the creation of a data set. In a step **410**, the instrument may be connected to system **100**, and system **100** may initiate an

instrument setup protocol in a step **420**. During instrument setup, data may be transmitted from instrument set-up subsystem **124** to the instrument and/or data may be received from the instrument by instrument set-up subsystem **124**. Data transmitted or received during a step **420** may comprise an environmental condition or parameter and/or instrument status information, which can include, for example, one or more instrument error message or information pertaining to instrument availability and scheduling). Instructions regarding experiment design may be received by experiment gateway module **120** from the application module **110** or from storage module **150** in a step **430** (e.g., as part of a client request or as automatically selected by system **100** as the result of a selection or preference indicated in a client request such as the selection of one or more specific type of analyzed data to be collected from a specific set of specimens) and may be transmitted to the instrument at a step **440**. Transmission of one or more experimental design to the instrument may be accompanied by or followed by instructions to execute the experiment design and collect one or more data set (e.g., experimental data). In a step **450**, data may be received from the instrument by a subsystem of gateway module **120**. For example, image data (e.g., as part of an experimental data set) may be received by image ingest subsystem **122**, and data related to the status of the data stream or the status of the instrument may be received by instrument monitoring subsystem **126**. Received data (e.g., raw experimental data) may be transmitted to application module **110** for display in real-time, near real-time, or batch mode in a step **460**. Data may also or may instead be transmitted to storage module **150**, interface module **140**, analysis engine module **130**, or any combination thereof (e.g., for storage, transmission to a computational tool **104** or an additional data acquisition tool **106**, or analysis).

[0090] In some embodiments, data received by instrument gateway module **120** can be stored in both short-term and long-term memory. For example, raw image data received from an instrument may be transmitted to a short-term memory cache to be displayed with extracted features and/or classification data after one or more analysis task has been completed, and it may also be transmitted to a long-term memory for long-term (e.g., cold) storage (e.g., storage module **150**). In some embodiments, the data stored in a short-term cache may be of high, intermediate, or low quality or resolution in order to reduce the amount of memory required. In some embodiments, data may be transmitted to and stored in a long-term storage memory in its highest resolution and/or quality.

[0091] Referring now to FIG. **5**, process **500** may be performed by system **100** for the purpose of analyzing data collected or stored by system **100**. As described herein, analysis of data, which can comprise feature extraction and/or classification, can be performed in real-time, near real-time, or batch mode. Analysis of data in batch mode may be advantageous or necessary, for example, because batch mode processing can reduce the computational cost of analysis. Experimental data can be received by analysis engine module **130** (e.g., in image processing subsystem **132**) from instrument gateway module **120** (e.g., from image ingest subsystem **122**) in a step **502**. Stored data to be analyzed can be received from storage module **150** (e.g., from image cache subsystem **156**) in a step **504**. Feature data (e.g., data comprising a feature data set) can be extracted from data received in step **502** or **504** by feature extraction subsystem **134** at a step **510**. Extracted feature data may be transmitted to application module **110** for display or storage module **150** for storage in steps **520** and **530**, respectively. Extracted feature data may be compiled into one or more classification data set and may be used by classification subsystem **136** to build (e.g., create, compile, or modify) a classification profile in a step **540**. Classification data and/or extracted feature data may be received from application module **110**, interface module **140** (e.g., as transmitted to the interface module or a subsystem thereof by a computational tool **104** or additional data acquisition tool **106**), and/or storage module **150** in step **550** for the purpose of building a classification profile as well. In some embodiments, classification data transmitted in step **550** may be accompanied by a set of training data (e.g., in order to build one or more classification profile, as in step **540**). A classification profile may optionally be transmitted to

application module **110**, interface module **140**, or storage module **150** in a step **560**. In some embodiments, building of a classification profile is unnecessary (e.g., when an existing classification profile is selected or supplied by the user), and one or more of steps **540**, **550**, or **560** may be omitted from process **500**. Building a classification profile, as in a step **540**, can comprise modifying an existing classification profile, which can comprise adding to, modifying, or deleting data from one or more classification data set from which the classification profile was originally built. In some embodiments, newly extracted feature data may be incorporated into one or more classification data set by analysis engine module **130** or a subsystem thereof. In a step **570**, a data set (e.g., a feature data set) can undergo classification analysis wherein one or more functional or phenotypic characteristic may be ascribed to or associated with a data set or experimental group. In some embodiments, data pertaining to one or more functional or phenotypic characteristic of a data set or experimental group can comprise a classification result. A classification result can be produced by the application of one or more classification profile, which can, in turn, comprise user-defined classification data and/or classification data produced by supervised or unsupervised machine learning techniques. In a step **580**, analyzed data, which may comprise a portion of a classification data set and/or one or more classification result, can be transmitted to application module **110** and/or storage module **150**.

[0092] FIG. **6** illustrates an embodiment of process **600** wherein data is transferred between platform system **101** and a computational tool **104** or an additional data acquisition tool **106** via interface module **140**. In a step **610**, a connection can be established between platform system **101** and the additional data acquisition tool **106** or computational tool **104**. The computational tool **104** or additional data acquisition tool **106** can be synchronized with interface module **140** at step **620**. Synchronization of the additional data acquisition tool with interface module **140** at step **620** may comprise transmission of data from the computational tool **104** or additional data acquisition tool **106** to storage API subsystem **146** or vice versa. A client request may be received at step **630**, for example, instructing an experiment comprising one or more imaging event to be performed using an additional data acquisition tool **106** or instructing one or more computational tool **104** or one or more additional data acquisition tool **106** to perform a data analysis procedure. In an optional step **640**, additional data may be received by interface module from another module or subsystem of platform system **101** concurrently or following step **630**. Data and/or a client request can be transmitted to one or more computational tool **104** or one or more additional data acquisition tool **106** in a step **650**. In a step **660**, data can be received from one or more computational tool **104** or one or more additional data acquisition tool **106** by one or more of the subsystems of interface module **140**, depending on what data is transmitted. At step **670**, data may be transmitted to application module **110** for display, instrument gateway module for image ingest, analysis engine module **130** for feature extraction and/or classification, and/or storage module **150** for storage.

[0093] Referring now to FIG. **7**, process **700** illustrates an embodiment of the operation of system **100**, wherein experimental data is acquired, analyzed, and displayed. In a step **710**, a client request can be received from application module **110** (e.g., from user terminal **102**). The client request can be transmitted to instrument gateway module **120** in a step **720**, which can, in some embodiments, include transmission of an experiment design from application module **110** to instrument gateway module **120** as well. In a step **730**, the data passed to instrument gateway module **120** can be transmitted to an instrument. In some embodiments, the instrument to which data is transmitted in step **730** is a computational tool **104** or an additional data acquisition tool **106**, in which case data transmission may be routed through interface module **140**, and in some embodiments, the instrument is not a computational tool **104** or an additional data acquisition tool **106**. In step **740**, experimental data, such as image data, can be received by instrument gateway module **120**. If one or more instrument with which the experimental data was produced is an additional data acquisition tool **106**, a portion of the data may be routed to instrument gateway module **120** via interface module **140**. In a step **750**, experimental data may be transmitted to storage module **150** for storage.

In a step **760**, the experimental data can be transmitted to application module **110** for display (e.g., in real-time, near real-time, or batch display mode). Experimental data can also be transmitted to analysis engine module **130** for analysis (e.g., feature extraction and/or classification) in a step **770**. Optionally, experimental data can be transmitted to interface module **140** in step **780** for transmission to a computational tool **104** or an additional data acquisition tool **106** and subsequent data analysis by the additional data acquisition tool. Following step **770** (e.g., or step **780** and subsequent receipt of analyzed data from a computational tool **104** or an additional data acquisition tool **106** via interface module **140**), analyzed data can be transmitted to application module **110** for display or to storage module **150** for storage.

[0094] The specific steps, their order, and the order of processes **300**, **400**, **500**, **600**, and **700** may be defined by a stored or custom experiment design and/or by additional selections or preferences inputted by a user. As such, one or more of processes **300**, **400**, **500**, **600**, or **700** may comprise additional steps, different steps, fewer steps, in accordance with embodiments of the systems, methods, and devices disclosed herein.

[0095] While preferred embodiments of the present invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

Claims

1.-**46**. (canceled)

47. A system for the classification of one or more specimens, the system comprising: a controller configured to: interface with one or more instruments through an instrument gateway module configured to receive a plurality of experimental data sets from the one or more instruments, wherein the plurality of experimental data sets is produced during a plurality of experiments, wherein the one or more instruments comprise a multi-spectral imager for fluorescence and bright field detection; extract one or more feature data sets from the plurality of experimental data sets; build one or more classification profiles based on a classification data set comprising at least a portion of the one or more feature data sets; and classify one or more specimens of an experiment of the plurality of experiments using the one or more classification profiles.

48. The system of claim 47, wherein the classification data set comprises at least a portion of each feature data set of a plurality of feature data sets, wherein a first portion of each feature data set is produced from a first experimental data set of the plurality of experimental data sets, and a second portion of each feature data set is produced from a second experimental data set of the plurality of experimental data sets.

49. The system of claim 48, wherein the first experimental data set and the second experimental data set are from different experiments.

50. The system of claim 48, wherein at least a portion of the first experimental data set and at least a portion of the second experimental data set are from different instruments.

51. The system of claim 47, wherein the one or more feature data sets comprise measurements of one or more color channels.

52. The system of claim 51, wherein the measurements of one or more color channels comprise one or more of intensity, absolute intensity, hue, saturation, and/or spatial changes in intensity.

53. The system of claim 47, wherein the one or more classification profiles are built using, at least in part, supervised machine learning or unsupervised machine learning.

54. The system of claim 47, wherein the one or more feature data sets are extracted based on

whether the one or more feature data sets meet or exceed a threshold value.

55. The system of claim 47, wherein the controller is further configured to display an analysis data set comprising at least a portion of the experimental data sets, at least a portion of the one or more feature data sets, or at least a portion of the classification data set, wherein the analysis data set is displayed in real-time, near-real time, or batch mode.

56. The system of claim 47, wherein the one or more specimens comprises one or more colonies of microbial cells.

57. A method for the classification of one or more specimens, the method comprising: receiving a plurality of experimental data sets from one or more instruments, wherein the plurality of experimental data sets is produced during a plurality of experiments, wherein the one or more instruments comprise a multi-spectral imager for fluorescence and bright field detection; extracting one or more feature data sets from the plurality of experimental data sets; building one or more classification profiles based on a classification data set comprising at least a portion of the one or more feature data sets; and classifying one or more specimens of an experiment of the plurality of experiments using the one or more classification profiles.

58. The method of claim 57, wherein the classification data set comprises at least a portion of each feature data set of a plurality of feature data sets, wherein a first portion of each feature data set is produced from a first experimental data set of the plurality of experimental data sets, and a second portion of each feature data set is produced from a second experimental data set of the plurality of experimental data sets.

59. The method of claim 58, wherein the first experimental data set and the second experimental data set are from different experiments.

60. The method of claim 58, wherein at least a portion of the first experimental data set and at least a portion of the second experimental data set are from different instruments.

61. The method of claim 57, wherein the one or more feature data sets comprise measurements of one or more color channels.

62. The method of claim 61, wherein the measurements of one or more color channels comprise one or more of intensity, absolute intensity, hue, saturation, and/or spatial changes in intensity.

63. The method of claim 57, wherein the building comprises use of supervised machine learning or unsupervised machine learning.

64. The method of claim 57, wherein the extracting is based on whether the one or more feature data sets meet or exceed a threshold value.

65. The method of claim 57, further comprising displaying an analysis data set comprising at least a portion of the plurality of experimental data sets, at least a portion of the one or more feature data sets, or at least a portion of the classification data set, wherein the analysis data set is displayed in real-time, near-real time, or batch mode.

66. The method of claim 57, wherein the one or more specimens comprises one or more colonies of microbial cells.