SYSTEMS AND METHODS FOR PROCESSING RETINAL SIGNAL DATA AND IDENTIFYING CONDITIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

[01] This application claims the benefit of U.S. Provisional Patent Application No. 63/000,055, filed March 26, 2020, U.S. Provisional Patent Application No. 63/038,257, filed June 12, 2020, and U.S. Provisional Patent Application No. 63/149,508, filed February 15, 2021, each of which is incorporated by reference herein in its entirety.

FIELD

[02] The present technology relates to systems and methods for processing retinal signal data generated by light stimulation.

BACKGROUND

[03] Clinicians may wish to determine whether a patient is subject to a medical condition, such as a psychiatric condition or a neurological condition. The clinician may compare the patient to known criteria in order to determine which condition a patient is subject to. In some instances, the patient may fit multiple conditions, and it may be difficult or impossible for the clinician to differentiate between the conditions. It may be preferable if the clinician had a tool to aid in determining and/or confirming whether a patient is subject to a medical condition and/or differentiating between those conditions.

[04] Embodiments of the present invention seek to ameliorate at least some of the limitations present in the prior art.

SUMMARY

[05] Embodiments of the present technology have been developed based on developers' appreciation of certain shortcomings associated with existing systems for determining medical conditions.

[09] In certain embodiments of the present technology, a more accurate detection of certain medical conditions or a more discriminant separation between medical conditions may be attained. The detection of medical conditions or discriminant separation between conditions may be attained within the diversity of related (e.g., gender, age, onset of disease, retinal pigmentation, iris color) and/or confounding factors (e.g. onset of conditions, use of drugs, effects of some treatments, episodes of psychosis, anxiety, depression, overlap of signs and symptoms common to several disorders). The increase in the level of detail and/or the number of retinal signal features the technology is able to capture and to analyse has a direct impact on the potential to identify biosignatures using retinal signal data in order to better discriminate between conditions, such as pathological conditions, as well as better depict the conditions as compared to a control (which may be referred to as a non-pathological condition). For example, embodiments of present methods may be based on retinal signal data captured at a higher sampling frequency and/or for a longer period of time compared to conventional ERG. The retinal signal data may include additional features recorded with the electrical signals, such as, but not limited to, impedance, light wavelength, light spectrum, or light intensity reaching the retina. The capture of additional information, at a higher sampling frequency, and/or data collected with an extended range of retinal light stimulation over an extended period of time, and its multi-dimensional representation, may be referred to as a "high density retinal signal data." The retinal signal data captured with high density may comprise more information than the data captured previously during an ERG (referred to as "conventional ERG"). The retinal signal data may be voltage-independent and/or time-independent, unlike conventional ERG.

[10] In certain embodiments, a more efficient processing of retinal signal data is possible using high density retinal signal data. The advantage of high density retinal signal data as compared to the conventional ERG data, is to benefit from a larger amount of information related to the electrical signals and additional retinal signal features and therefore a more detailed biosignature. With a higher level of detail, it is therefore possible to better discriminate among different conditions and prepare a series of classifiers representative of the biosignature features of each condition.

[11] According to a first aspect of the present invention, there is provided a method for generating a mathematical model corresponding to a first condition, the method executable by at

least one processor of a computer system, the method comprising: receiving a plurality of datasets of labelled retinal signal data corresponding to a plurality of patients, wherein each dataset comprises retinal signal data of a patient and a label, wherein the label indicates whether the patient is subject to the first condition; extracting a set of features from the retinal signal data; selecting a subset of features from the set of features, wherein the subset of features corresponds to biomarkers of the first condition; and determining, based on the subset of features, one or more classifiers that distinguish the first condition from a second condition.

[12] In some implementations of the method, the set of features comprise voltage, circuit impedance, signal collection time, sampling frequency, light stimulation synchronization time, light stimulation offset, or indications of which retinal areas were illuminated.

[13] In some implementations of the method, the set of features comprise eye position, pupil size, intensity of applied luminance, frequency of light stimulation, frequency of retinal signal sampling, wavelength of illumination, illumination time, background wavelength, or background luminance.

[14] In some implementations of the method, the one or more classifiers distinguish a biosignature of the first condition from a biosignature of the second condition.

[15] In some implementations of the method, the method further comprises ranking the set of features based on a relevance of each feature to the biosignature of the first condition, and wherein selecting the subset of features comprises selecting highest-ranked features of the set of features.

[16] In some implementations of the method, the method further comprises: receiving clinical information cofactors corresponding to the plurality of patients, wherein each dataset comprises clinical information cofactors of the patient; and selecting a subset of the clinical cofactors, wherein the clinical cofactors in the subset of clinical cofactors influence detection of the biomarkers.

[27] In some implementations of the method, the retinal signal data comprises one or more optical parameters.

[28] In some implementations of the method, the optical parameters comprise luminance of retinal light stimulation or pupil size.

[29] According to a second aspect of the present invention, there is provided a method for predicting a probability that a patient is subject to one or more conditions, the method executable by at least one processor of a computer system, the method comprising: receiving retinal signal data corresponding to the patient; extracting, from the retinal signal data, one or more retinal signal features; extracting, from the retinal signal features, one or more descriptors; applying the one or more descriptors to a first mathematical model and a second mathematical model, wherein the first mathematical model corresponds to a first condition and the second mathematical model corresponds to a second condition, thereby generating a first predicted probability for the first condition and a second predicted probability for the second condition; and outputting the first predicted probability and the second predicted probability.

[30] In some implementations of the method, the method further comprises displaying an interface comprising the first predicted probability and the second predicted probability.

[31] In some implementations of the method, the method further comprises storing the first predicted probability and the second predicted probability.

[32] In some implementations of the method, the method further comprises collecting the retinal signal data.

[33] In some implementations of the method, the method further comprises: obtaining clinical information cofactors extracted from clinical information corresponding to the patient; and applying the clinical information cofactors to the first mathematical model and the second mathematical model.

[34] In some implementations of the method, the clinical information cofactors correspond to an age, gender, skin pigmentation, or iris color of the patient.

[35] In some implementations of the method, the retinal signal data has a sampling frequency between 4 to 24 kHz.

[36] In some implementations of the method, the retinal signal data is collected for a signal collection time of 200 milliseconds to 500 milliseconds.

[37] In some implementations of the method, the retinal signal data comprises an impedance component of a receiving circuit recorded continuously while capturing the retinal signal data.

[38] In some implementations of the method, the retinal signal data comprises one or more optical parameters.

[39] In some implementations of the method, the optical parameters comprise luminance of retinal light stimulation or pupil size.

[40] In some implementations of the method, the first condition is a medical condition and wherein the second condition is a control condition.

[41] In some implementations of the method, the first condition or the second condition is schizophrenia, bipolar disorder, major depression disorder, or psychosis.

[42] In some implementations of the method, the first condition or the second condition is post-traumatic stress disorder, stroke, substance abuse, obsessive compulsive disorder, Alzheimer's, Parkinson's, multiple sclerosis, autism, or attention deficit disorder.

[43] In some implementations of the method, the method further comprises receiving user input indicating a selection of the first condition and the second condition.

[44] In some implementations of the method, the method further comprises: selecting, based on the first predicted probability and the second predicted probability, a medication; and administering the medication to the patient.

[45] According to a third aspect of the present invention, there is provided a method for determining a biosignature of a condition, the method executable by at least one processor of a computer system, the method comprising: receiving a plurality of datasets of labelled retinal

signal data corresponding to a plurality of patients, wherein each dataset comprises retinal signal data of a patient and a label, wherein the label indicates whether the patient is subject to the condition; extracting a set of features from the retinal signal data; selecting a subset of features from the set of features, wherein the subset of features corresponds to biomarkers of the condition; and determining, based on the subset of features, one or more classifiers that identify the biosignature of the condition.

[46] In some implementations of the method, the method further comprises: receiving clinical information cofactors corresponding to the plurality of patients, wherein each dataset comprises clinical information cofactors of the patient; and selecting a subset of the clinical cofactors, wherein the clinical cofactors in the subset of clinical cofactors influence detection of the biomarkers, and wherein determining the one or more classifiers comprises determining, based on the subset of clinical cofactors, the one or more classifiers.

[47] In some implementations of the method, the method further comprises ranking the set of features based on a relevance of each feature to the biosignature of the first condition, and wherein selecting the subset of features comprises selecting highest-ranked features of the set of features.

[47a] According to a fourth aspect of the present invention, there is provided a system comprising at least one processor and memory storing a plurality of executable instructions which, when executed by the at least one processor, cause the system to perform the method defined in the first, second and third aspects.

[47b] According to a fifth aspect of the present invention, there is provided a non-transitory computer-readable medium containing instructions which, when executed by a processor, cause the processor to perform the method defined in the first, second and third aspects.

[48] According to a sixth aspect of the present invention, there is provided a system for predicting a probability that a patient is subject to one or more conditions, the system comprising: a light stimulator; one or more sensors; a computer system comprising at least one processor and memory storing a plurality of executable instructions which, when executed by the at least one processor, cause the computer system to: cause the light stimulator to provide light stimulation signals to retina of the patient; collect, via the one or more

sensors, electrical signals responsive to the light stimulation; generate, based on the electrical signals, retinal signal data corresponding to the patient; extract, from the retinal signal data, one or more retinal signal features; extract, from the retinal signal features, one or more descriptors; apply the one or more descriptors to a first mathematical model and a second mathematical model, wherein the first mathematical model corresponds to a first condition and the second mathematical model corresponds to a second condition, thereby generating a first predicted probability for the first condition and a second predicted probability for the second condition; and output the first predicted probability and the second predicted probability.

[49] In some implementations of the system, the retinal signal data comprises a light wavelength component recorded while capturing the retinal signal data.

[50] In some implementations of the system, the retinal signal data comprises a light spectrum component recorded while capturing the retinal signal data.

[51] In some implementations of the system, the retinal signal data comprises a light intensity component recorded while capturing the retinal signal data.

[52] In some implementations of the system, the retinal signal data comprises an illuminated retinal surface component recorded while capturing the retinal signal data. The retinal surface component may indicate a surface area of the retina that is illuminated.

[53] According to a seventh aspect of the present invention, there is provided a system for predicting a probability that a patient is subject to one or more conditions, the system comprising a computer system comprising at least one processor and memory storing a plurality of executable instructions which, when executed by the at least one processor, cause the computer system to: receive retinal signal data corresponding to the patient; extract, from the retinal signal data, one or more retinal signal features; extract, from the retinal signal features, one or more descriptors; apply the one or more descriptors to a first mathematical model and a second mathematical model, wherein the first mathematical model corresponds to a first condition and the second mathematical model corresponds to a second condition, thereby generating a first predicted probability for the first condition and a second predicted probability for the second condition; and output the first predicted probability and the second predicted probability.

[54] In some implementations of the system, the system further comprises a light stimulator and one or more sensors, and the instructions, when executed by the at least one processor, cause the computer system to: cause the light stimulator to provide light stimulation signals to retina of the patient; collect, via the one or more sensors, electrical signals responsive to the light stimulation; and generate, based on the electrical signals, the retinal signal data.

[55] In some implementations of the system, the system further comprises a display, and wherein the instructions, when executed by the at least one processor, cause the system to output,

via the display, an interface comprising the first predicted probability and the second predicted probability.

[56] According to an eighth aspect of the present invention, there is provided a method for monitoring a condition of a patient, the method executable by at least one processor of a computer system, the method comprising: receiving retinal signal data corresponding to the patient; extracting, from the retinal signal data, one or more retinal signal features; extracting, from the retinal signal features, one or more descriptors; applying the one or more descriptors to a mathematical model corresponding to the condition, thereby generating a predicted probability for the condition; and outputting the predicted probability.

[57] In some implementations of the method, the method further comprises: selecting, based on the predicted probability, a medication; and administering the medication to the patient.

[58] In some implementations of the method, the retinal signal data comprises retinal signal data captured during treatment of the patient for the condition.

[59] In some implementations of the method, the condition is schizophrenia, bipolar disorder, major depression disorder, psychosis, post-traumatic stress disorder, stroke, substance abuse, obsessive compulsive disorder, Alzheimer's, Parkinson's, multiple sclerosis, autism, or attention deficit disorder.

[60] In the context of the present specification, unless expressly provided otherwise, a computer system may refer, but is not limited to, an "electronic device," an "operation system," a "system," a "computer-based system," a "controller unit," a "control device," and/or any combination thereof appropriate to the relevant task at hand.

[61] In the context of the present specification, unless expressly provided otherwise, the expression "computer-readable medium" and "memory" are intended to include media of any nature and kind whatsoever, non-limiting examples of which include RAM, ROM, disks (CD-ROMs, DVDs, floppy disks, hard disk drives, etc.), USB keys, flash memory cards, solid state-drives, and tape drives.

[62] In the context of the present specification, a "database" is any structured collection of data, irrespective of its particular structure, the database management software, or the computer hardware on which the data is stored, implemented or otherwise rendered available for use. A database may reside on the same hardware as the process that stores or makes use of the information stored in the database or it may reside on separate hardware, such as a dedicated server or plurality of servers.

[63] In the context of the present specification, unless expressly provided otherwise, the words "first," "second," "third," etc. have been used as adjectives only for the purpose of allowing for distinction between the nouns that they modify from one another, and not for the purpose of describing any particular relationship between those nouns.

[64] Embodiments of the present technology each have at least one of the above-mentioned aspects, but do not necessarily have all of them.

[65] Additional and/or alternative features, aspects and advantages of embodiments of the present technology will become apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[66] For a better understanding of the present technology, as well as other aspects and further features thereof, reference is made to the following description which is to be used in conjunction with the accompanying drawings, where:

[67] Figure 1 is a block diagram of an example computing environment in accordance with various embodiments of the present technology;

[68] Figure 2 is a block diagram of a retinal signal processing system in accordance with various embodiments of the present technology;