

Accordingly, the claimed subject matter is intended to embrace all such alterations, modifications, and variations that fall within the spirit and scope of the appended claims.

[0060] In regard to the various functions performed by the above described components, devices, circuits, systems and the like, the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., a functional equivalent), even though not structurally equivalent to the disclosed structure, which performs the function in the herein illustrated exemplary aspects of the claimed subject matter. In this regard, it will also be recognized that the foregoing implementations include a system as well as a computer-readable storage media having computer-executable instructions for performing the acts and/or events of the various methods of the claimed subject matter.

[0061] There are multiple ways of realizing the foregoing implementations (such as an appropriate application programming interface (API), tool kit, driver code, operating system, control, standalone or downloadable software object, or the like), which enable applications and services to use the implementations described herein. The claimed subject matter contemplates this use from the standpoint of an API (or other software object), as well as from the standpoint of a software or hardware object that operates according to the implementations set forth herein. Thus, various implementations described herein may have aspects that are wholly in hardware, or partly in hardware and partly in software, or wholly in software.

[0062] The aforementioned systems have been described with respect to interaction between several components. It will be appreciated that such systems and components can include those components or specified sub-components, some of the specified components or sub-components, and/or additional components, and according to various permutations and combinations of the foregoing. Sub-components can also be implemented as components communicatively coupled to other components rather than included within parent components (e.g., hierarchical components).

[0063] Additionally, it is noted that one or more components may be combined into a single component providing aggregate functionality or divided into several separate sub-components, and any one or more middle layers, such as a management layer, may be provided to communicatively couple to such sub-components in order to provide integrated functionality. Any components described herein may also interact with one or

Wherefore, what is claimed is :

1. A system for detecting the onset of drowsiness in an individual, comprising:
 - one or more heart rate (HR) sensors which capture HR information of the individual over time, the HR information comprising heart rate variability (HRV) information;
 - one or more computing devices, said computing devices being in communication with each other whenever there is a plurality of computing devices, and a drowsiness onset detector computer program having a plurality of sub-programs executable by the one or more computing devices, the one or more computing devices being directed by the sub-programs of the drowsiness onset detector computer program to,
 - receive the HR information from the heart rate sensor or sensors,
 - extract a plurality of different HRV-related features from the HR information, said extracted different HRV-related features, which are among many features that can be extracted from HR information, having been determined to be specifically indicative of a transition from a wakeful state of an individual to a drowsy state of an individual,
 - combine the extracted different HRV-related features to produce a drowsiness detection input,
 - input the drowsiness detection input into an artificial neural network (ANN) classifier that has been trained to distinguish between said wakeful state of an individual and said drowsy state of an individual based on the extracted different HRV-related features,
 - identify from an output of the ANN classifier if the drowsiness detection input indicates that the individual is exhibiting an onset of drowsiness, and
 - whenever the drowsiness detection input indicates that the individual is exhibiting an onset of drowsiness, initiate a drowsiness onset warning.
- 2 . The system of claim 1, wherein the HR information comprises a raw HR signal captured by the one or more HR sensors, and wherein the sub-program for extracting a plurality of different HRV-related features from the HR information comprises first computing a HRV signal from the raw HR signal.
- 3 . The system of claim 1, wherein the one or more HR sensors comprise a computing device which comprises a HRV signal from a raw HR signal captured by the HR sensor or sensors, and wherein the HR information comprises the HRV signal.
4. The system of claim 1, wherein the one or more heart rate (HR) sensors and the one or more computing devices are resident in a unified drowsiness onset detection device.
5. The system of claim 4, wherein the drowsiness onset detection device is either a wearable device worn on the person of said individual, or a mobile device carried by said individual.

6. The system of claim 1, wherein the one or more heart rate (HR) sensors are resident in a wearable device worn on the person of said individual, and the one or more computing devices are resident in a mobile device carried by said individual, and wherein the wearable device is in wireless communication with the mobile device.

7. The system of claim 6, wherein the HR information comprises a raw HR signal captured by the one or more HR sensors which is transmitted to said mobile device carried by the individual.

8. The system of claim 6, wherein the HR information comprises a raw HR signal captured by the one or more HR sensors, and wherein the one or more HR sensors comprise a computing device which computes a HRV signal from the raw HR signal, said HRV signal being transmitted to said mobile device carried by the individual.

9. The system of Claim 1, further comprising a segmenting sub-program that is executed before the execution of the sub-program for extracting a plurality of different HRV-related features from the HR information, said segmenting sub-program segmenting the HR information received from the heart rate sensor or sensors into a sequence of prescribed-length segments whenever the received HR information is in the form of a HRV signal, and said segmenting sub-program computing a HRV signal from the received HR information whenever the received HR information is not in the form of a HRV signal before segmenting the HRV signal into the sequence of prescribed-length segments, and wherein the sub-programs for extracting a plurality of different HRV-related features from the HR information, combining the extracted different HRV-related features, inputting the drowsiness detection input into the ANN classifier, identifying from an output of the ANN classifier if the drowsiness detection input indicates that the individual is exhibiting an onset of drowsiness, and whenever the drowsiness detection input indicates that the individual is exhibiting an onset of drowsiness, initiating a drowsiness onset warning, are executed on each of the HRV signal segments as they are created.

10. The system of claim 9, wherein the prescribed-length segments of the HRV signal are each two minutes in length and represent a rolling window such that there is a prescribed offset time between each segment.

11. The system of claim 10, wherein each two minute long HRV signal segment represents approximately 120 heart rate variation values, and wherein the segmenting subprogram further comprises up-sampling each HRV signal segment to approximately 840 samples heart rate variation values using curve fitting techniques.

12. The system of claim 9, wherein the sub-program for extracting a plurality of different HRV-related features from each HRV signal segment comprises extracting the plurality of different HRV-related features using a Discrete Fast Fourier Transform (DFFT) and a Discrete Wavelet Transform (DWT).

13. The system of claim 12, wherein the DFFT is used to compute a ratio of the power of the low frequency components of the HRV signal segment to the power of the high frequency (HF) components of the HRV signal segment as one of the extracted different HRV-related features, and wherein the DWT is used to compute from an 8-level decomposition of the HRV segment the D_i through D_8 entropy coefficients, A_8 entropy coefficient and the mean of the A_i through A_8 entropy coefficients as others of the extracted different HRV-related features.

14. The system of claim 1, wherein the sub-program for initiating a drowsiness onset warning comprises initiating a wake-up call to the individual in the form of a message that is displayed on a display screen that is viewable by the individual.

15. The system of claim 14, wherein the message comprises at least one of text, or images, or flashing images that appear as a flashing light on the display screen.

16. The system of claim 1, wherein the sub-program for initiating a drowsiness onset warning, comprises initiating a wake-up call to the individual in the form of an audible alert that is played over speakers which are within a hearing range of the individual.

17. The system of claim 1, wherein the sub-program for initiating a drowsiness onset warning, comprises initiating a wake-up call to the individual in the form of a haptic alert that can be felt by the individual.

18. The system of claim 1, wherein the sub-program for initiating a drowsiness onset warning, comprises transmitting a message to a third party requesting the third party to warn the individual.

19. A system for detecting the onset of drowsiness in an individual, comprising:

- one or more computing devices, said computing devices being in communication with each other, whenever there is a plurality of computing devices; and
- a drowsiness onset detector computer program having a plurality of subprograms executable by one or more computing devices, the one or more computing devices being directed by the sub-programs of the drowsiness onset detector computer program to,
 - receive heart rate (HR) information of the individual over time, the HR information comprising heart rate variability (HRV) information, wherein the one or more computing devices are in communication over a data communication network with a remote computing device associated with one or more HR sensors which capture the HR information, and wherein the HR information is received from the remote computing device via the data communication network;
 - extract a plurality of different HRV-related features from the HR information, said extracted different HRV-related features, which are among many features that can be extracted from HR information, having been determined to be specifically indicative of a transition from a wakeful state of an individual to a drowsy state of an individual,
 - combine the extracted different HRV-related features to produce a drowsiness detection input,
 - input the drowsiness detection input into an artificial neural network (ANN) classifier that has been trained to distinguish between said wakeful state of an individual and said drowsy state of an individual based on the extracted different HRV-related features,

identify from an output of the ANN classifier if the drowsiness detection input indicates that the individual is exhibiting an onset of drowsiness, and

whenever the drowsiness detection input indicates that the individual is exhibiting an onset of drowsiness, transmit a drowsiness onset notification.

20. A drowsiness onset detection classifier training system, comprising :

one or more computing devices, said computing devices being in communication with each other via a computer network whenever there is a plurality of computing devices; and

a drowsiness onset detector training computer program having a plurality of sub-programs executable by the one or more computing devices, the one or more computing devices being directed by the sub-programs of the drowsiness onset detector training computer program to,

receive the HR information output by one or more heart rate sensors for a plurality of individuals over time, as well as a drowsiness indicator for each of the individuals specifying whether that individual is in a wakeful state or in a drowsy state at the time the HR information was captured, the HR information comprising heart rate variability (HRV) information, for the HR information associated with each of the plurality of individuals,

extract a plurality of different HRV-related features from the HR information, said extracted different HRV-related features, which are among many features that can be extracted from HR information, having been determined to be specifically indicative of a transition from a wakeful state of an individual to a drowsy state of an individual, and

combine the extracted different HRV-related features to produce a drowsiness detection input, and train an artificial neural network (ANN) classifier to distinguish between said wakeful state of an individual and said drowsy state of an individual using said the drowsiness detection inputs and drowsiness indicator associated with each of the plurality of individuals.