SYSTEM FOR TRANSMISSION AND DIGITIZATION OF MACHINE TELEMETRY

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to the field of digitized imagery for the state of a machine, and more particularly, for monitoring the changing state based on imaging of analog or other physical state conditions of an apparatus that take place as the change occurs.

2. Brief Description of the Related Art

[0002] With the ubiquity of global communications links, much of the world and its machines can be connected rapidly and easily to other machines and digital control systems on a worldwide basis. It is now possible to create digital control loops and employ global networks to enable machines to directly communicate important information to other machines (so-called M2M applications), to enable automated decision making without the intervention of humans. However, unlike human-to-human communications which may be in the form of voice or images, M2M applications generally require the transmission of digital data. One common part of many M2M applications today is simply converting analog telemetry and signals from a machine into a digital form, suitable for transmission over the internet. Examples, without limitation, include converting the electrical signals that drive analog type gauges on a mobile machine like a vehicle, boat or airplane, or which drive the gauges a remotely located machine like an oil rig or switch gear in a switch yard, into digital representations of said signals and sending the resulting digital representations of the electrical signals to another location via wired or wireless internet for further action or monitoring by another machine, or human. However, many machines are designed originally with gauges and indicator lights which are intended only for humans to view them, and enabling such machines to transmit a digital version of their indicator lights or gauges requires extensive modifications to the machine and interruption of the electrical signaling

systems in such machines. The effort required to perform the analog to digital conversion or even the copying of already digital information gauges into a form transmittable over the internet, reduces the rate of adoption of M2M communication functions in system applications that could benefit. Furthermore, some machines present regulatory or safety or warranty difficulties in converting them to be able to send digital information from their control systems or gauges. For example the high voltages in switch gear or motor control gear must be fully isolated from the low voltage circuits that normally digitize and communicate data over the internet; gauges and wiring on an aircraft cannot be tampered with or changed without affecting the aircraft's airworthiness certificate; new circuitry to digitize analog gauges, or to tap into signals already present in digital form on a vehicle cannot be easily added without violating the warranty on the vehicle.

[0003] What is needed is a system for digitizing gauges, lights and other human-readable machine gauges and functions and status without interfering with the operation of the machine or requiring re-working or interfering with the existing machine wiring, signaling, electrical or mechanical elements or operating modes, or adding new digitizing equipment to the machine.

SUMMARY OF THE INVENTION

[0004] The present invention provides a system for digitizing devices, such as gauges, lights and other human-readable machine gauges and functions and status. The system operates without the need to reconfigure operations or electronic components of the device being monitored. The potential for adversely interfering with the operation of the machine is eliminated, and there is no need to re-work any of the machine components or interfere with the existing machine wiring, signaling, electrical or mechanical elements or operating modes.

In addition the system may be implemented using equipment configured by the system, which does not require the addition of new digitizing equipment to the machine.

[0005] These and other advantages may be provided by the invention.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0006] Figure 1 is a preferred embodiment of the invention, depicting in perspective view a camera and a panel, and showing a diagram of a preferred implementation of the system according to a first exemplary embodiment.

[0007] Figure 2 is front elevation view of the panel of Fig. 1 with an enlarged extracted image portion showing a specific meter of the panel, and process depictions according to an exemplary implementation of the system.

[0008] Figure 3 is a front elevation view showing a digital panel meter and process depictions according to an exemplary implementation of the system.

[0009] Figure 4A is a depiction of an exemplary frame used to illustrate the image capture of a motor.

[0010] Figure 4B is a depiction of the exemplary frame in Figure 4A showing an exemplary variance region of an image capture area.

[0011] Figure 5 is a graph representing an exemplary depiction showing image variation of an operating device for captured images over a period of time.

DETAILED DESCRIPTION OF THE INVENTION

[0012] A preferred embodiment of the invention, called the image-M2M system, is depicted in Figure 1. In the preferred embodiment, a panel with meters, indictors and switches, 101, is being monitored and any or all of the indicators are being digitized by the invention. Note that other than either ambient or purposeful illumination, the light reflected off of the panel, 101A (without departing from generality may be infrared light or other non-

visible wavelengths) is the only relationship between the panel and the invention, and there is no physical or electric connection between the invention and the machine being monitored whatsoever. A camera, 102, is physically placed in the vicinity of the machine being monitored so that its field of view, 101A, covers one or more gauges or lights or control panels to be monitored. According to some alternate embodiments, the camera may comprise an infrared-capable camera (and according to some embodiments the camera is capable of imaging both visible and infrared illumination). An infrared illumination means may be provided (*e.g.*, separately, as part of the camera, or in association therewith) to illuminate the panel so that panels in dark rooms or at night may be captured by the camera. The resolution of the camera 102 is chosen to be sufficient to give a sufficient granularity on a pixel basis to provide the necessary resolution desired for the ultimate digitization of each meter or indicator. The camera, 102, takes pictures of the panel. The rate of the picture frames may be either intermittent based on a frame timer 104 which is programmed either manually, or remotely via a local control system which may contain within it either a general or special purpose processor for executing a software or firmware program 106A, or a processing function implemented either in hardware, software or a combination of the two, which captures frames of the panel only when a change in the panel itself occurs, 103, or the camera may produce continuous video, 105. The frames or video are optionally compressed, formatted and encrypted, 106, and then made available to be either proactively sent or retrieved on demand by supervisory circuitry or computer 106A. It should be understood that all of the functions 102, 103, 104, 105, 106 and 106A may be combined in a single implementation in hardware, software or firmware on a single processor and may optionally be entirely contained with camera 102 and all of the functions may be optionally controlled by the supervisory control computer 106A. These elements comprise what is termed the remote system 100.

[0013] The images are then communicated over a network connection 107, which may be the internet, or a private communications link, and of which one or more segments may be electrically wired, optically linked, or wirelessly linked via a terrestrial wireless link or a satellite wireless link. This network connection 107 may also serve to provide command and control directives to the Supervisory control circuitry 106A. The images provided by the remote system 100 arrive at separate supervisory and control circuitry, 108A, and subsequent decompression, formatting and decryption functions 108. The resulting images can then be stored either permanently or temporarily in a memory or other electronic storage device 109. Subsequently, extraction and digitization algorithms are employed 110, 111, which, as further described below, turns each image into a sequence of digital values associated with any or all of the indicators, meters, gauges or switches in the image of the panel. The extraction algorithm 110 and digitization algorithm 111 may be pre-programmed or may operate selectively on various parts of the panel on a request basis, and may include optical character recognition (OCR) sub-algorithms. The results may then optionally be stored in a memory device 112, which can then be accessed by either a private communications system, such as a SCADA network, or a standards based network such as the internet. By the many means well known to those practiced in the art, the data available in memory 112 may be presented to the internet as individually addressable, or as sub-addressable, data elements. As indicated, all of the functions 108a, 108, 109, 110, 111 and 112 may be contained within a single sub-system of hardware and software, 120, or within only software operating on a larger server farm (not shown).

[0014] In the above manner, one or more indicators, readouts, meters and the like may become digital numbers, each addressable at an address or sub-address over the internet, without any direct connection to, or interference with, the operation of the said indicators in the panel 101.

[0015] The change detection function 103 may be programmed to provide for the capture of a frame or video when any external object interrupts the view of the panel or meters, such as a human operator adjusting controls or taking other actions. In this way, the invention provides additional security and information which would not necessarily be present in a simple digital telemetry stream which were formed by digitization of the signals within the panel itself. Also, the remote system 100 can be programmed to recognize certain alarm conditions such as a specific indicator light, or a hot temperature and instigate communications with the local system on its own.

[0016] Now the readout extraction and digitization algorithms will be described, with reference to Figures 2 and 3. In the case of an analog type meter in Figure 2, on the local system when the first instance of image capture occurs where there are many indicators, meters or gauges which may not need to be digitized, each meter to be digitized from the larger image 201 is extracted into a sub-image 202, using a simple master mask or other simple sub-image extraction algorithm well known, and available in many common off-the-shelf image processing packages, such as Matlab. An image mask 201A can be automatically or one-time manually created to assist the sub-image creation step. Once the sub-image of a particular meter or indicator is created, depending on the type of meter, various straightforward image processing and extraction methods can be employed to ascertain the meter reading. For example, for the meter in 203, a Hough transform can be employed to ascertain automatically the angle of the indicator from horizontal, and that angle associated in a table with indicated meter values. For a generalized method, a reference image of the meter at each possible indication discernible by the pixilation of the image can be stored *a priori* in the local processing system, where each image is associated with a digital value indicated by the meter, and correlated against the sub-image 203 to determine which of the reference images is the closest match to the received sub-image. There are many other image

processing methods generally well known to those practiced in the art of image processing that may be employed in step 203 without departing from the current invention. At the conclusion of step 203, the meter or indicator value 204 is stored in the local system as a digital value, in this case negative five.

[0017] Referring to Figure 3, after sub-image creation, an existing digital panel meter 301 can be easily converted into a digital value 303 from a sub-image through simple optical character recognition program 302, which are generally available in off-the-shelf software.

[0018] The image-M2M invention system can also add additional functions to the image processing, such as perspective de-warping in the case where a camera is not mounted head-on to a meter or indicator, or where a large panel is imaged, without departing from the invention. Libraries of common meters may be maintained for easy manual and/or automated initial setup.

[0019] The image-M2M invention presented has the advantages of being able to adapt to a wide variety of gauges, meters and indicators, including many which may not be easily amenable to digitization with traditional embedded telemetry measurement and analog-to-digital electrical or mechanical techniques. In addition, through the use of the camera and the image system, many meters or indicators may be captured and digitized at once. Furthermore, the image-M2M system can provide additional information not normally available from traditional telemetry, such as when an employee operated a dial, inspected a machine, or similar environmental or incidental events which would otherwise go unrecorded. In addition, a camera may be focused on a motor or engine or set of pulleys or belts, and may make a frame-to-frame comparison to determine the amount of vibration or torque movement in the motor or engine, providing information which would otherwise be very difficult to ascertain remotely, even with sophisticated telemetry.

[0020] According to one exemplary embodiment, the system is configured with one or more cameras which are focused on one or more aspects of a motor or engine, including connected or associated components, such as, for example, drive or driven mechanisms. For example, a camera is positioned to have its focus directed to the engine or motor, or operating portion or component. The camera images the field of view and provides an image frame that is comprised of an image area A. The image area A is illustrated in Figures 4A and 4B showing an exemplary depiction of an image frame. In the image area A shown in Figure 4A, there is a depiction of a motor 310, which is a captured image of a motor. The motor image 310 takes up a portion of the image area A. The motor image area preferably represents image coordinates, which may comprise pixels. In the depiction of the solid line motor 310 of Figure 4A, the motor 310 is shown in a static state, represented by the motor image area A*ms*. The broken-line depictions represent the motor 310 at operating positions, where the motor 310 during operation is vibrating. The images captured of the operating motor 310 within the frame area A are at different locations within the frame area A, and are represented by the motor positions A*m1*, A*m2*, A*m3* (three different positions being shown for illustration purposes). Although the vibrational motor positions are shown in a two dimensional coordinate depiction in the figures, according to alternate embodiments, the system may be configured to account for movement that is forward (into the plane of the page) or rearward (out of the plane of the page), in addition to, or alternative to, the two dimensional plane.

[0021] The motor image area or an operating motor A*o* may be set to image area coordinates within which the motor 310 is imaged when operating, and more preferably, when operating within acceptable ranges. In this example, the range represents an acceptable vibration level. The motor vibration is imaged by the motor positioning within the image area A. The motor image area may represent a number of separate motor images A*m1*, A*m2*,

A*m3*, ... A*mN*, where each separate image corresponds with a set of image coordinates or pixels of the image frame capture (at different times), which, in this example, may be represented by the image area A. The image coordinates of each image may be used to determine an operation parameter, which, in this example, is a vibration level, and an acceptable vibration level. Referring to Figure 4B, in this example, an image area or boundary of an operating motor image location is represented by A*o*. The image area A*o* of the operating motor may be generated by the represented motor positions within the camera frame that correspond with acceptable positions as a result of vibrational movement or disturbances of the operating motor under acceptable operating conditions. The motor 310 may be imaged in a non-operating state to provide a static image A*ms* (see Figure 4A), which represents the motor static position level within the frame or area A. The vibrational variances may be determined by the position of the motor 310 within the image area A at a given time, or over a given time interval or series of frames. For example, where the boundary of acceptable motor vibration Ao is exceeded, an operating event may be detected and recorded. The system may be configured with software containing instructions to detect operating events, and generate a response when an operating event has been detected (such as a positive detection result). For example, some responses may include recording the event to a log, issuing an alert, notifying a particular individual or machine (computer), to shutting down the device (the motor in this example), or combinations of these.

[0022] According to some implementations, the system is configured to process the motor image A*mT* (where, for example, the motor image A*m* represents an image at a particular time *T*), and compare the pixels or coordinates of the motor image location on the image field to determine whether the motor image parameters have been breached. The breach may be confirmed by a determination that the processed image reveals the motor (*e.g.*, portion thereof) being detected at a position within the frame that is outside of a designated

motor image boundary area, which in this example is the motor image boundary area A*o*. For example, where A*o* defines a set of coordinates within which the motor imaging is acceptable for the motor position or location, and a motor image breaches the coordinate boundary, a positive detection result may be recorded. According to some embodiments, pixel locations and values of the motor images may be compared (for example, to an absolute value or reference value), to determine whether a breach of an acceptable operating condition has occurred.

[0023] Alternately, the motor vibration may be determined with reference to a deviation from the static image position A*ms*. For example, the separate images A*m1*, A*m2*, A*m3*, ... A*mN* of the motor during operation of the motor may provide image coordinates that are different than the static image coordinates A*ms* (although it is possible that some of the images A*m1*, ... A*mN* may correspond with the status image A*ms* as the motor is operating). A variance level may be determined for the image area of an operating motor, and the camera may operate as shown and described herein, with continuous imaging, or a frame rate imaging, which ascertains an image of the motor. Referring to Figure 5, a plot of motor image change or variation ΛA*m* from a static condition image (A*ms*) over time T is shown. The graph depicts an acceptable variance range region, and variant range regions outside of the acceptable range region. The range or variance parameters may be designated and predetermined based on accepted movements or vibrations of the motor during normal operations or operations deemed to be acceptable. The variance may be provided to proscribe when motor vibrations exceed an acceptable or threshold level, which is represented by the motor imaging locations within an image frame, and as the motor imaging locations may be represented by pixels or coordinates.

[0024] According to some alternate embodiments, the system may be configured to image a particular portion of a component, such as the motor. For example, a pulley wheel,

or a portion thereof, such as, the top portion, may be imaged, and when its radial portion being imaged is detected to have breached an arc range (*e.g.*, as defined by the frame coordinates), which previously was determined to be an acceptable operating range, a positive detection result may be initiated. In addition, an alert or other operation may be generated.

[0025] The system may be configured to generate a response to a positive detection (where the motor vibration is detected and determined to be operating outside of acceptable parameters), which may be from storing the result for later use in maintenance, or to relay an instruction to shut down the motor, or any other response, which may be to send an alert to an operator or technician (and allow the motor to continue). In addition, the vibration level image data may be processed and stored, as images, or as processed information. The vibration levels may be provided to recreate motor movements that were imaged. In addition, the vibration image data, such as, for example, the position of the motor within a frame, or processed vibration data ascertained from the images, may be time-stamped to provide an indication of the time of operation. This may be useful to determine whether there is a particular load, time of day, or operation that produces an associated motor operation.

[0026] Although the example is provided in conjunction with a motor, other operating components may be used and imaged, and the image information processed to determine whether the component operation is within an acceptable operation parameter or condition. In addition, a plurality of cameras may be provided to image a respective plurality of components, and the images of multiple components may be determined and detected by the system.

[0027] Furthermore, the camera system may be augmented with audio information or an audio track which can record the sounds of buzzers, alarms or other audible signaling which is otherwise unobservable by the image system. Also, the sounds of motors or engines

may be recorded so that if they begin to make unusual sounds, a local action can be taken for what might otherwise be an unobserved remote phenomenon.

[0028] These and other advantages may be realized with the present invention. While the invention has been described with reference to specific embodiments, the description is illustrative and is not to be construed as limiting the scope of the invention. Although a plurality of motor images are shown on the image frame A of Figure 4A, the images may represent an image captured on separate frames and represent separately captured image frames. Various modifications and changes may occur to those skilled in the art without departing from the spirit and scope of the invention described herein and as defined by the appended claims.

CLAIMS:

What is claimed is:

1. A system for use with existing devices to provide monitoring of a change in state, the system comprising:

a) a camera;

b) a subsystem having a supervisory computer or control circuitry;

c) a communications component for communicating images obtained with the camera to the subsystem;

d) wherein the subsystem is configured to receive the communicated images and has a processor and software containing instructions for storing the communicated images and for manipulating the images;

e) wherein the system manipulates the images by extracting and digitizing the images;

f) wherein the device is a motor, and wherein the camera captures images of the motor and processes the images to determine a condition of the motor operation;

g) wherein the condition of operation is motor vibration;.

h) wherein each of the images captured comprises a frame having a frame area, wherein said motor is imaged in said frame area, wherein said motor when operating is captured at different locations within the frame area; wherein said capture locations of the motor are evaluated to determine the motor operating condition;. and

i) wherein (i) an acceptable vibration state is defined by a vibration area of the image frame represented by a set of coordinates; or (ii) said frame area comprises coordinates defining locations within the frame, wherein said motor images are represented by coordinates, wherein said motor image coordinates determine a vibration state of the motor.

2. The system of claim 1, wherein extracting and digitizing of an image comprises extracting and digitizing a selective portion of the image, wherein the image comprises a

panel representation, and wherein the selected portion of the image represents a location on the panel where a readable element is located.

3. The system of claim 2, wherein the readable element comprises a gauge, meter, switch, dial, light, or indicator.

4. The system of claim 1, wherein said camera and said communications component for communicating images are configured together and include one or more processing components with circuitry for processing the images from the camera.

5. The system of claim 4, including a frame timer for regulating the frequency of the image capture rate.

6. The system of claim 4, wherein said one or more processing components include at least one processor coupled with said circuitry to execute software containing instructions for regulating the capture of images to capture frames of the panel when a change in the panel being imaged occurs.

7. The system of claim 1 or 2, comprising a first subsystem and a second subsystem, wherein the first subsystem includes the camera and communications component, and wherein the second subsystem comprises the subsystem having a supervisory computer or control circuitry.

8. The system of claim 7, wherein the first subsystem includes a change frame detection mechanism which processes the image data obtained with the camera, identifies when a change in the device being monitored has occurred, and actuates the capture of image frames of the device being monitored when a change in the monitored device is detected.

9. The system of claim 8, wherein the device being monitored comprises a panel.

10. The system of claim 9, wherein the panel includes a monitored component, and wherein the change frame detection mechanism is configured to identify when a change to the monitored component has occurred.

11. The system of claim 10, wherein the monitored component comprises a meter.

12. The system of claim 8, wherein a plurality of cameras are provided, and wherein the device being monitored includes a plurality of components to be respectively monitored by the respective plurality of cameras.

13. The system of claim 12, wherein the plurality of cameras are provided in a single housing.

14. The system of claim 7, wherein said first subsystem includes a frame timer for regulating the frequency of the image capture rate.

15. The system of claim 7, wherein said first subsystem is configured to capture continuous video from the camera.

16. The system of claim 8 or 15 wherein said first subsystem is configured to process the image frame or video by compressing, formatting, encrypting, or one or more of these processes.

17. The system of claim 7, wherein the first subsystem includes a supervisory computer or control circuitry that is coupled to receive image inputs from the camera, and wherein the first subsystem is configured to manipulate the camera images by:

a) regulating the frequency of the image capture rate with a frame timer;

b) processing the image frame or video by one or more of compressing, formatting, or encrypting the image frame or video; and

c) transmitting the processed image frame or video to the second subsystem.

18. The system of claim 17, wherein the first subsystem comprises a remote subsystem, and wherein the second subsystem receives processed image frames or video from the first subsystem, and wherein the second subsystem is configured to manipulate the processed image frames or video by:

a) processing the image frame or video by one or more of decompressing, formatting, or decrypting the image frames or video received from the first subsystem;

b) storing the image frames or video in a memory or storage component; and

c) generating a sequence of digital values for the extracted and digitized image.

19. The system of claim 18, wherein said device monitored comprises a panel having a plurality of readable elements thereon, wherein said readable elements include at least one first readable element and at least one second readable element; wherein extracting at least one portion of the image includes extracting from the image at least a first portion of the image that contains the image of the first readable element and extracting from the image at least a second portion of the image that contains the image of the second readable element; wherein digitizing the extracted image portion to generate a sequence of digital values is done for each extracted image to generate a sequence of digital values for the first readable element, and a second sequence of digital values for the second readable element.

20. The system of claim 18, wherein the first subsystem comprises a first supervisory computer or control circuitry, and wherein the second subsystem supervisory computer or control circuitry comprises a second supervisory computer or control circuitry.

21. The system of claim 7, wherein said communications component of the first subsystem is provided as part of the camera.

22. The system of claim 7, wherein the first subsystem comprises a remote subsystem which is remote in proximity to said second subsystem.

23. The system of claim 1, wherein said image processing comprises processing an image of a device that is an analog component and displays an analog value thereon, and wherein digitization comprises generating a digital value for the analog value.

24. The system of claim 1, wherein the camera comprises an infrared-capable camera.

25. The system of claim 24, including an infrared illumination means.

26. The system of claim 1, wherein said communications component comprises a communications link.

27. The system of claim 26, wherein said communications component comprises a wireless cellular link.

28. The system of claim 26, wherein the communications link includes a cellular wireless portion.

29. The system of claim 26, wherein the communications link includes a satellite wireless portion.

30. The system of claim 1, including change detection means for detecting changes of the image captured when the image captures something other than the meter within the image frame or designated portion of the image frame.

31. The system of claim 1, wherein the system is configured with software containing instructions for processing images received from the camera, and determining whether the image is an image panel or portion, or is something other than the image panel or portion.

32. The system of claim 1, including change detection means for detecting change, wherein change detection includes the entry of an object or hand into a view which triggers the sending of a frame or video.

33. The system of claim 32, wherein the camera and change detection system is used remotely to monitor the vibration of a motor or engine.

34. The system of claim 33, wherein the camera and change detection system is used to monitor the loading or torque on a motor or engine.

35. The system of claim 1, including sound detection means comprising a sensor for detecting an audible event.

36. The system of claim 35, comprising a first subsystem and a second subsystem, wherein the first subsystem comprises a remote subsystem which is remote in proximity to

the second subsystem and includes the camera and communications component, wherein the second subsystem comprises a subsystem having a supervisory computer or control circuitry, and wherein detection of an audible event comprises ascertaining whether a buzzer, alarm, or audible warning, has been actuated within the proximity of the remote subsystem.

37. The system of claim 1, wherein the system generates an alert when the motor vibration determined by the camera images is not operating within the acceptable vibration state.

38. The system of claim 2, including a local control system that controls the camera based on a frame rate, a change in the panel itself, or a combination of these.

39. The system of claim 7, wherein said communications component comprises a communications link, and wherein the first subsystem receives command and control directives from a communications link.

40. The system of claim 9, wherein the panel includes the readable element, and wherein the system applies a sub mask to generate a sub-image of the readable element.

41. The system of claim 1, including a device library containing initial set up parameters for a plurality of devices to be digitized, wherein a device of the device library may be selected to apply settings that direct the camera and image processing operations.