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(54) **WORK MODE CONTROL METHOD AND OPTICAL ENCODER USING THE SAME**

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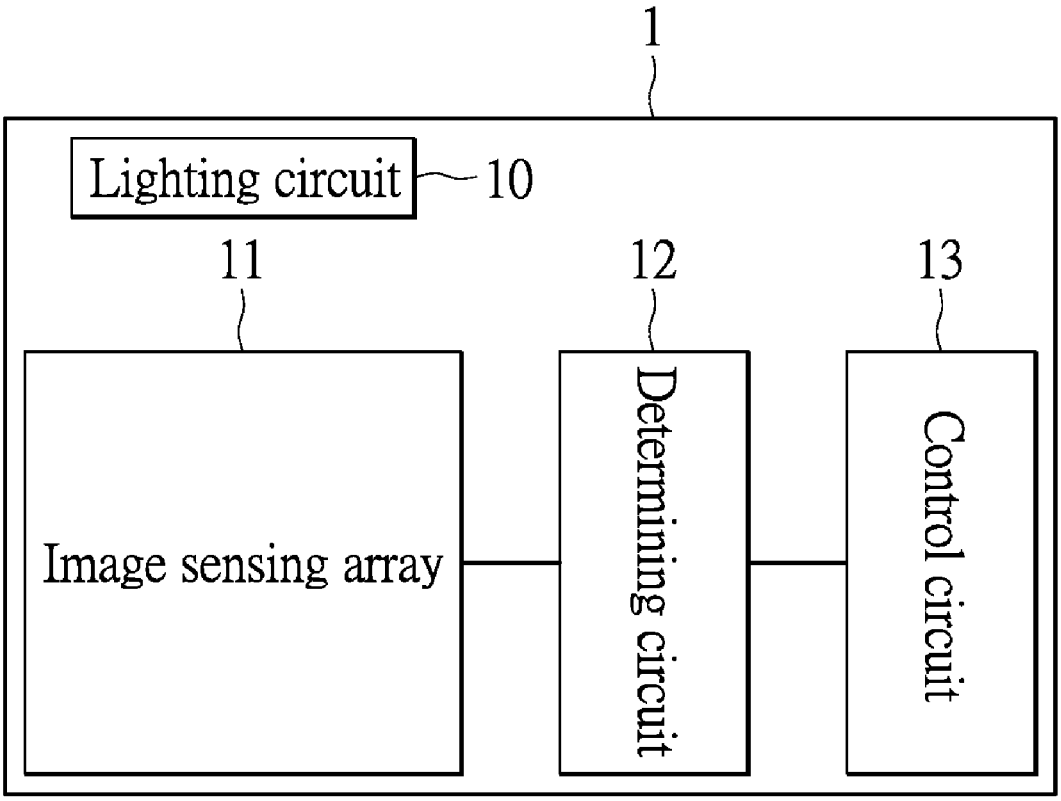
(57) **ABSTRACT**

The present disclosure illustrates a work mode control method. The work mode control method includes the following steps. First, capturing an image once every capturing interval. Next, determining a shutter time, an average brightness and an image quality in response to the images. The shutter time is associated with a frequency of the optical encoder to capture the images. The average brightness is associated with a brightness of environmental light sensed by the optical encoder. The image quality is associated with clarity of the images. Then, adjusting a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality. Finally, controlling the optical encoder to enter a rest mode when the shutter time is higher than a first threshold, the average brightness is higher than a second threshold, and the image quality is lower than a third threshold.



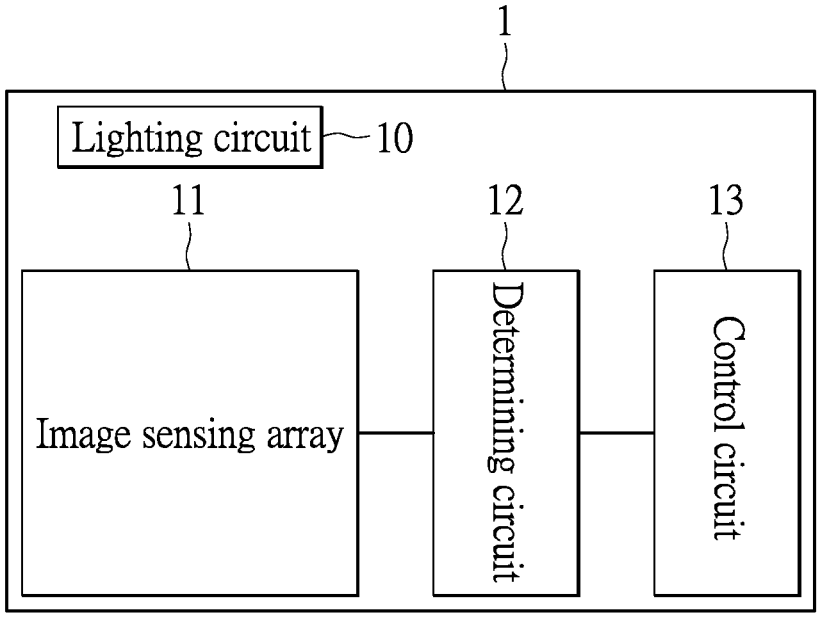

1
Lighting circuit
10
11
12
13
Image sensing array
Determining circuit
Control circuit

FIG.1

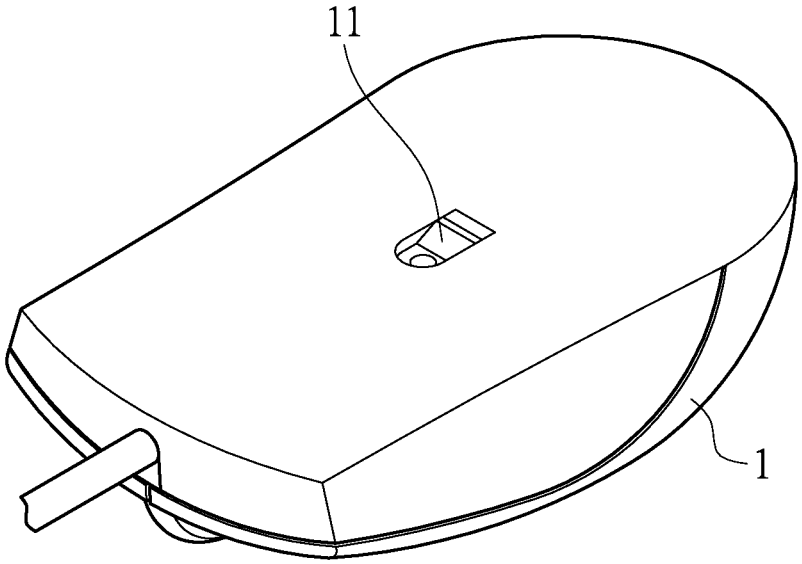


FIG.2

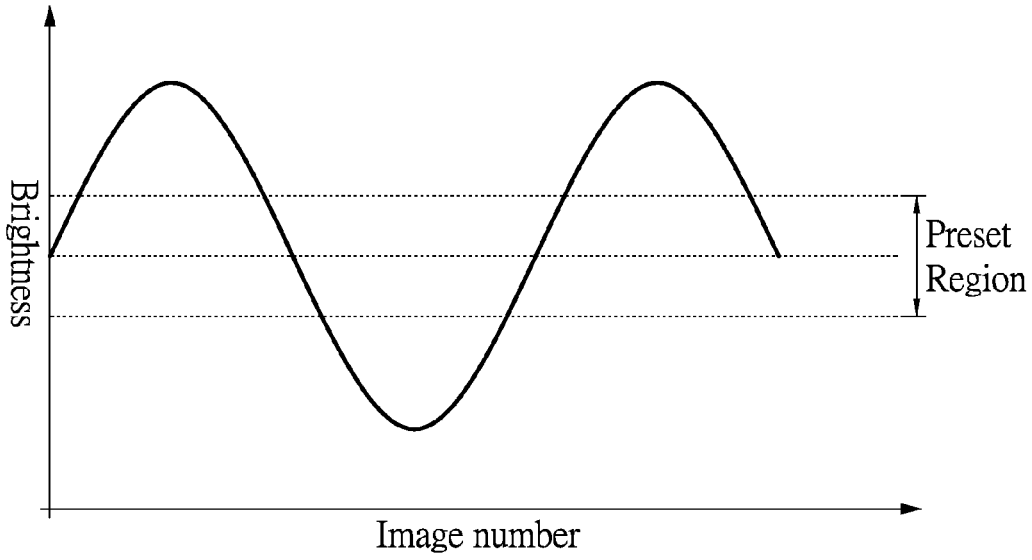


FIG.3

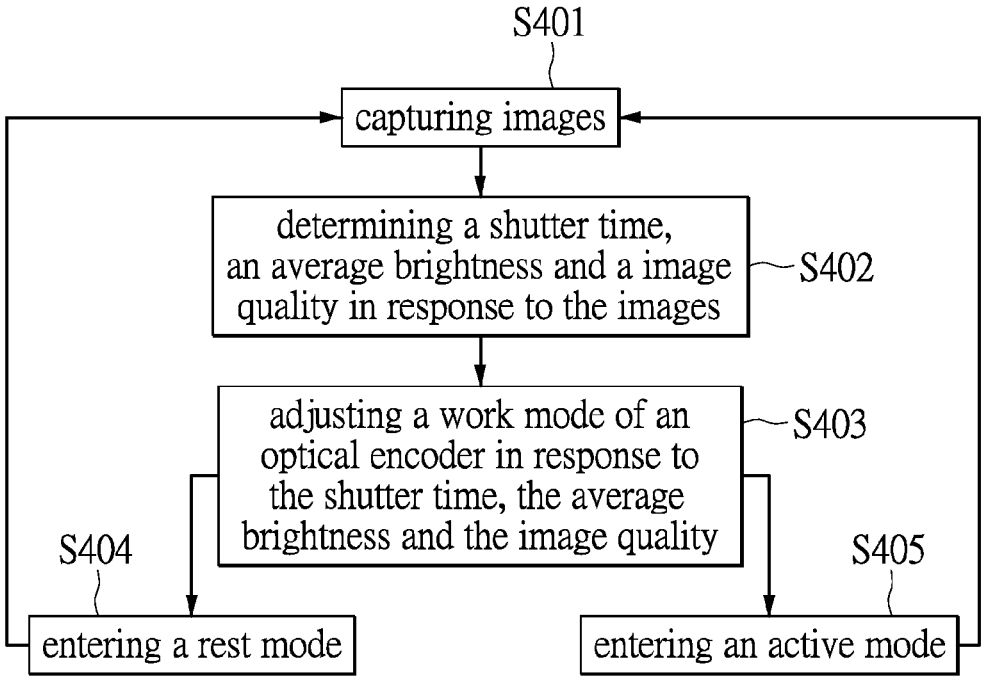

S401
capturing images
determining a shutter time, an average brightness and a image quality in response to the images
S402
adjusting a work mode of an optical encoder in response to the shutter time, the average brightness and the image quality
S403
S404
S405
entering a rest mode
entering an active mode

FIG.4

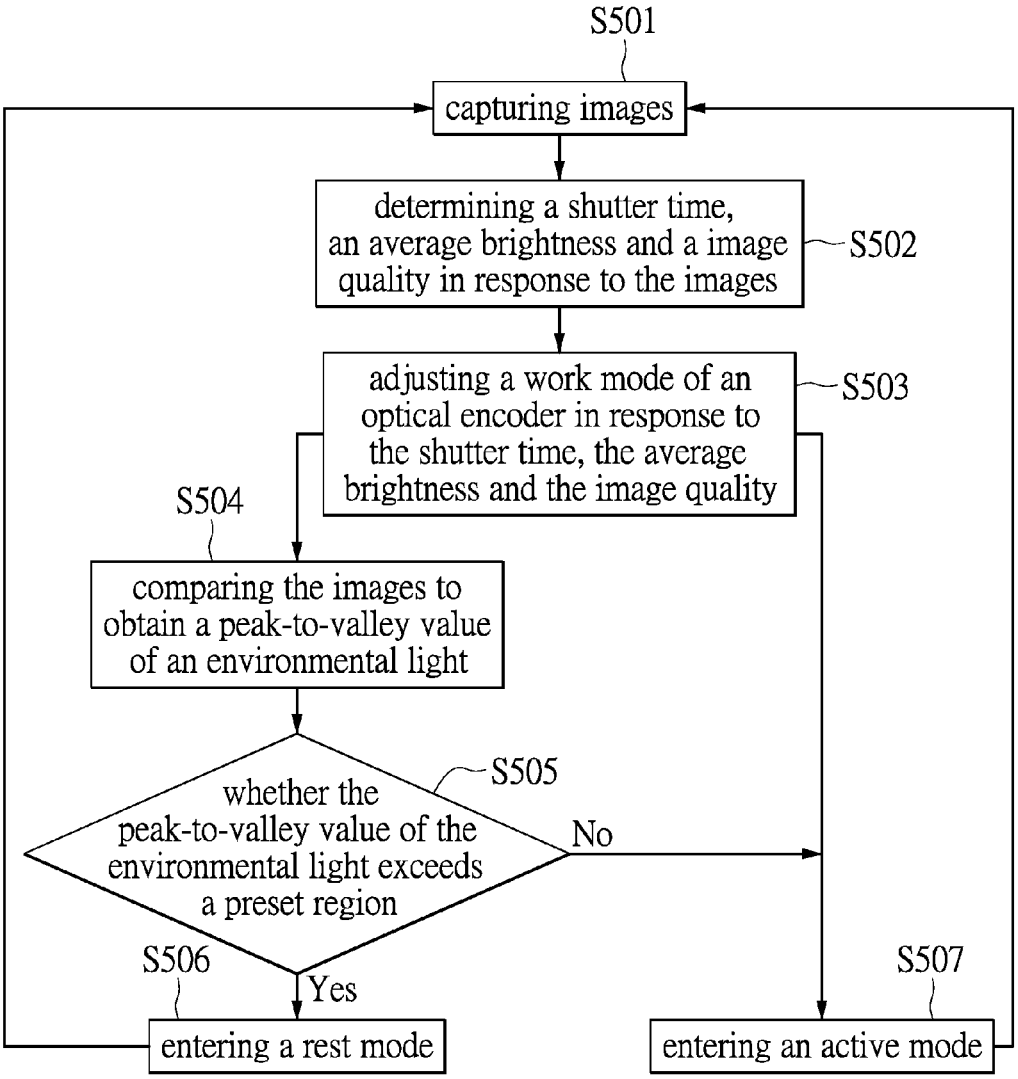

S501
capturing images
determining a shutter time, an average brightness and a image quality in response to the images
S502
adjusting a work mode of an optical encoder in response to the shutter time, the average brightness and the image quality
S503
S504
comparing the images to obtain a peak-to-valley value of an environmental light
whether the peak-to-valley value of the environmental light exceeds a preset region
S505
No
Yes
S506
entering a rest mode
S507
entering an active mode

FIG.5

WORK MODE CONTROL METHOD AND OPTICAL ENCODER USING THE SAME

BACKGROUND

[0001] 1. Technical Field

[0002] The present disclosure relates to a work mode control method for an optical encoder, in particular, to the work mode control method which can adjust a work mode of the optical encoder based on a current environment, and the optical encoder using the same.

[0003] 2. Description of Related Art

[0004] With the development of technology, optical encoders have become popular. The most common optical encoder is an optical mouse. Users can control a cursor displayed on an electronic device through the optical mouse, wherein the electronic device is such as a desktop computer or a notebook computer.

[0005] The optical encoder usually includes a lighting circuit and an image sensor having a miniature digital camera, wherein the lighting circuit is configured for operatively irradiating a working surface. The image sensor includes an image sensing array, and the image sensing array includes a plurality of pixels to capture images associated with a part of the working surface irradiated by the lighting circuit. According to the captured images, a control circuit of the optical encoder outputs a control signal to the electronic device, such that the electronic device implements a corresponding function.

[0006] In order to save power, an optical encoder which can adjust work mode based on current environment is developed, as the current optical encoder cannot accurately determine the environment to decrease power consumption.

SUMMARY

[0007] An exemplary embodiment of the present disclosure provides a work mode control method for an optical encoder. The work mode control method comprises the following steps. Step a: capturing an image once every capturing interval. Step b: determining a shutter time, an average brightness and an image quality in response to the images. The shutter time is associated with a frequency of the optical encoder to capture the images. The average brightness is associated with a brightness of an environmental light sensed by the optical encoder. The image quality is associated with clarity of the images. Step c: adjusting a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality. Step d: controlling the optical encoder to enter a rest mode when the shutter time is higher than a first threshold, the average brightness is higher than a second threshold, and the image quality is lower than a third threshold.

[0008] An exemplary embodiment of the present disclosure provides an optical encoder. The optical encoder comprises an image sensing array, a determining circuit and a control circuit. The determining circuit is coupled to the image sensing array. The control circuit is coupled to the determining circuit. The image sensing array is configured for operatively capturing an image once every capturing interval. The determining circuit is configured for operatively receiving the images and determining a shutter time, an average brightness and an image quality in response to the images. The shutter time is associated with a frequency of the optical encoder to capture the images. The average brightness is associated with a brightness of environmental light sensed by the optical encoder. The image quality is associated with clarity of the images.

[0009] In summary, the work mode control method and the optical encoder using the same provided by the instant disclosure can accurately determine the operating state of the optical encoder. As the optical encoder is put in the abnormal state, the optical encoder is switched to the rest mode to save power. The control circuit is configured for operatively adjusting a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality. The control circuit controls the optical encoder to enter a rest mode when the shutter time is higher than a first threshold, the average brightness is higher than a second threshold, and the image quality is lower than a third threshold.

[0010] In order to further understand the techniques, means and effects of the present disclosure, the following detailed descriptions and appended drawings are hereby referred to, such that, and through which, the purposes, features and aspects of the present disclosure can be thoroughly and concretely appreciated; however, the appended drawings are merely provided for reference and illustration, without any intention to be used for limiting the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The accompanying drawings are included to provide a further understanding of the present disclosure, and are incorporated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the present disclosure and, together with the description, serve to explain the principles of the present disclosure.

[0012] FIG. **1** shows a block diagram of an optical encoder of one embodiment of the present disclosure.

[0013] FIG. **2** shows a schematic diagram of an optical encoder in an abnormal state of one embodiment of the present disclosure.

[0014] FIG. **3** shows a brightness waveform diagram of environmental light sensed by an optical encoder of one embodiment of the present disclosure.

[0015] FIG. **4** shows a flow diagram of a work mode control method for an optical encoder of one embodiment of the present disclosure.

[0016] FIG. **5** shows a flow diagram of a work mode control method for an optical encoder of other embodiment of the present disclosure.

DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0017] Reference will now be made in detail to the exemplary embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0018] Notably, the terms first, second, third, etc., may be used herein to describe various elements or signals, but these signals should not be affected by such elements or terms. Such terminology is used to distinguish one element from another or a signal with another signal. Further, the term "or" as used herein in the case may include any one or combinations of the associated listed items.

[0019] Please refer to FIG. **1**. FIG. **1** shows a block diagram of an optical encoder of one embodiment of the present disclosure. An optical encoder **1** includes a lighting circuit **10**, an image sensing array **11**, a determining circuit **12** and a control circuit **13**. The image sensing array **11** is coupled to the determining circuit **12**. The control circuit **13** links with an electronic device via wireless communication or wire communication, wherein the electronic device is such as a desktop computer or a notebook computer.

[0020] The optical encoder **1** is such as an optical mouse, a smart watch or a joystick. Users can operate the optical encoder **1** to control the electronic device connected with the optical encoder **1**, or control the optical encoder **1** to generate a corresponding result. In the exemplary embodiment, the optical encoder **1** is a kind of optical mouse.

[0021] The lighting circuit **10**, such as a light emitting diode, comprises suitable logic, circuitry, interfaces and/or code operable to provide a light beam to irradiate a working surface which the optical encoder **1** is working on.

[0022] The image sensing array **11** includes a plurality of pixels. Generally, the image sensing array **11** is correspondingly disposed to the working surface. The image sensing array **11** receives the reflected light which the working surface has reflected from the light beam, and captures an image associated with a part of the working surface according to the reflected light once every capturing interval.

[0023] The determining circuit **12** comprises suitable logic, circuitry, interfaces and/or code operable to receive the images outputted by the image sensing array **11**, and determines a current operating state of the image sensing array **11** in response to the images.

[0024] To put it concretely, the determining circuit **12** determines a shutter time, an average brightness of the light beam and an image quality of each image in response to the image. The shutter time represents a turning-on time of the image sensing array **11** that the image sensing array **11** is turned on and starts to capture the images. In other words, the shutter time is associated with how much light beam the working surface reflects to the image sensing array **11**. If a color of the working surface is a bright color, such as a white paper, the more light beam is reflected to the image sensing array **11**. At this moment, the shutter time is decreased. If the color of the working surface is dark color, such as a dark paper, most of the light beam is absorbed by working surface. Then, the optical encoder **1** increases the shutter time. Or, if the optical encoder **1** is lifted, the image sensing array **11** receives only a little reflected light, and then the shutter time is also increased.

[0025] The determining circuit **12** can determine the current shutter time using a first threshold. If the shutter time is higher than the first threshold, the determining circuit **12** determines the shutter time is high, and outputs a first determining signal with logic high level. In contrast, if the shutter time is lower than the first threshold, the determining circuit **12** determines the shutter time is low, and outputs a first determining signal with logic low level.

[0026] The light beam sensed by the image sensing array **11** may be the reflected light provided by the working surface. Or, when an operating state of the optical encoder **1** changes, the light beam sensed by the image sensing array **11** may be environmental light provided by another light source, wherein the operating state is associated with how the user uses the optical encoder **1**. Based on the captured images, the determining circuit **12** can calculate the average brightness of the light beam irradiating on the image sensing array **11**. The determining circuit **12** can determine the current average brightness using a second threshold. If the average brightness is higher than the second threshold, the determining circuit **12** determines the average brightness is high, and outputs a second determining signal with logic high level. In contrast, if the average brightness is lower than the second threshold, the determining circuit **12** determines the average brightness is low, and outputs a second determining signal with logic low level.

[0027] Generally, the shutter time is inversely proportional to the average brightness sensed by the image sensing array **11**. When the average brightness decreases as sensed by the image sensing array **11**, the control circuit **13** increases the shutter time. Due to the image sensing array **11** has longer time to collect the light beam, the image sensing array **11** captures brightness images.

[0028] The image quality is associated with clarity of each image. The higher the clarity, the higher the image quality is. The determining circuit **12** can determine the current image quality using a third threshold. If the image quality is higher than the third threshold, the determining circuit **12** determines the image quality is high, and outputs a third determining signal with logic high level. In contrast, if the image quality is lower than the third threshold, the determining circuit **12** determines the image quality is low, and outputs a third determining signal with logic low level.

[0029] Furthermore, the determining circuit **12** can determine the image quality by comparing the two images captured by two proximate pixels. When the brightness of the two images are very different, such as the brightness of one of the images is high and the brightness of the other one of the images is low, the determining circuit **12** determines that the environmental light correctly focuses on the image sensing array **11**, such that the two images captured by the two proximate pixels can show the brightness difference clearly. Accordingly, the determining circuit **12** outputs the third determining signal with logic high level.

[0030] To sum up, the determining circuit **12** can determine the shutter time, the average brightness and the image quality in response to the images outputted by the image sensing array **11**, and then outputs determining signals to the control circuit **13**.

[0031] The control circuit **13** comprises suitable logic, circuitry, interfaces and/or code operable to receive the determining signals outputted by the determining circuit **12**, and controls a work mode of the optical encoder **1** correspondingly. For example, if all of the first, second and third determining signals are logic high level, the control circuit **13** determines that the optical encoder **1** is now normally working. Next, the control circuit **13** controls the optical encoder **1** to enter an active mode, and provides power to each element disposed in the optical encoder **1**. On the other hand, according to the operating state of the optical encoder **1**, the control circuit **13** can switch the optical encoder **1** to enter a rest mode, and selectively stops providing power to a part of the elements disposed in the optical encoder **1**. Accordingly, the optical encoder **1** can decrease power consumption.

[0032] Please refer to FIG. **2**. FIG. **2** shows a schematic diagram of an optical encoder in an abnormal state of one embodiment of the present disclosure. The user can put the optical encoder **1** into the operating state shown in FIG. **2** when the user does not want to use the optical encoder **1**.

The optical encoder **1** looks like an inverted turtle at this moment, so hereafter this abnormal state is referred to as "turtle state".

[0033] When the optical encoder **1** is in the turtle state, the image sensing array **11** faces the environmental light directly. In other words, the image sensing array **11** is directly irradiated by the environmental light instead of receiving the reflected light provided by the working surface. The optical encoder **1** increases the shutter time of the image sensing array **11** because of the environmental light directly irradiates the image sensing array **11**. Then, the determining circuit **12** outputs the first determining signal with logic high level.

[0034] On the other hand, the average brightness sensed by the image sensing array **11** increases because the environmental light directly irradiates the image sensing array **11**, and the brightness of the images captured by the image sensing array **11** also increases. Then, the determining circuit **12** outputs the second determining signal with logic high level.

[0035] Incidentally, the average brightness is also associated with the material of the working surface. When the optical encoder **1** is in normal working state instead of in the turtle state, the image sensing array **11** receives the reflected light provided by the working surface. The brightness of the reflected light increases when the color of the working surface is too light, or the working surface easily reflects the light beam, such that the average brightness sensed by the image sensing array **11** increases.

[0036] Next, due to the environmental light directly irradiating on the image sensing array **11**, the environmental light is unable to focus on the image sensing array **11**. The image sensing array **11** captures only fuzzy images which have low image quality. Then, the determining circuit **12** outputs the third determining signal with logic low level.

[0037] After receiving the first, second determining signals with logic high level and the third determining signal with logic low level, the control circuit **13** determines the optical encoder **1** is in the turtle state shown in FIG. **2**, and controls the optical encoder **1** to enter the rest mode. In brief, the control circuit **13** automatically switches the optical encoder **1** to enter the rest mode to save power as long as the user puts the optical encoder **1** in the turtle state.

[0038] In the exemplary embodiment, the control circuit **13** controls the optical encoder **1** to enter the rest mode when the control circuit **13** receives the first, second determining signals with logic high level and the third determining signal with logic low level. However, the present invention is not limited thereto. Those skilled in the art can design a switch condition based on need, such that the control circuit **13** switches the optical encoder **1** to enter the rest mode if the first, second and third determining signals meet the switch condition. For example, the control circuit **13** controls the optical encoder **1** to enter the rest mode when the control circuit **13** receives the first, second and third determining signals with logic low level.

[0039] In the above exemplary embodiment, the determining circuit **12** determines whether the optical encoder **1** is in the abnormal state based on the images captured by the image sensing array **11**. Notably, in another exemplary embodiment, the determining circuit **12** further obtains a brightness waveform diagram through detecting the brightness of the environmental light, and determines whether the optical encoder **1** is in the abnormal state based on the brightness waveform diagram.

[0040] Please refer to FIG. **3**. FIG. **3** shows a brightness waveform diagram of an environmental light sensed by an optical encoder of one embodiment of the present disclosure. In FIG. **3**, the vertical axis of the brightness waveform diagram represents the brightness of the environmental light, and the horizontal axis of the brightness waveform diagram represents the number of the images captured by the image sensing array **11**. For example, the image sensing array **11** can capture 2000 images per second, and obtains the brightness waveform diagram based on these images.

[0041] The environmental light is not maintained at the same brightness, but the human eye can not detect the environmental light is flashing. The brightness waveform diagram of the environmental light is similar to a waveform diagram of a sinusoidal wave. According to the images captured by the image sensing array **11**, the determining circuit **12** can determine a peak value and a valley value of the brightness of the environmental light, and further calculates a peak-to-valley value of the environmental light.

[0042] First, the determining circuit **12** determines the shutter time, the average brightness and the image quality according to the above steps to generate the first, second and the third determining signals, such as the first and second determining signals with logic high level and the third determining signal with logic low level. Next, the determining circuit **12** calculates the peak value and the valley value of the environmental light, and further obtains the peak-to-valley value in response to the peak value and the valley value. If the peak-to-valley value does not exceed a preset region (such as the preset region shown in FIG. **3**), meaning that the brightness of the environmental light is not high enough, the determining circuit **12** outputs a fourth determining signal with logic low level to the control circuit **13**. The control circuit **13** will not control the optical encoder **1** to enter the rest mode when the control circuit **13** receives the fourth determining signal with logic low level.

[0043] In contrast, if the peak-to-valley value exceeds the preset region, meaning that the brightness of the environmental light is too high, the determining circuit **12** outputs a fourth determining signal with logic high level to the control circuit **13**. The control circuit **13** determines that the optical encoder **1** is in the abnormal state (such as the turtle mode shown in FIG. **2**). Then, the control circuit **13** controls the optical encoder **1** to enter the rest mode for decreasing power consumption.

[0044] Incidentally, the determining circuit **12** calculates the peak-to-valley value in the exemplary embodiment. In another exemplary embodiment, the determining circuit **12** transmits the peak value and the valley value of the environmental light to the control circuit **13**, and then the control circuit **13** calculates the peak-to-valley value based upon the peak value and the valley value to switch the optical encoder **1** to a suitable work mode.

[0045] Please refer to FIG. **4**. FIG. **4** shows a flow diagram of a work mode control method for an optical encoder of one embodiment of the present disclosure. The work mode control method provided in FIG. **4** is suitable for the optical encoder as mentioned above. In step S**401**, an image sensing array of the optical encoder captures an image once every capturing interval, and transmits the captured image to a determining circuit of the optical encoder. In step S**402**, the determining circuit determines a shutter time, an average

brightness and an image quality in response to the images, and generates first, second and third determining signals.

[0046] In step S**403**, a control circuit adjusts a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality. If the first, second determining signals are with logic high level and the third determining signal with logic low level, the control circuit determines the optical encoder is in an abnormal state now, such as the turtle mode shown in FIG. **2**, and then step S**404** is executed. Conversely, if the first determining signal is not logic high level, the second determining signal is not logic high level and the third determining signal is not logic low level, step S**405** is executed.

[0047] In step S**404**, the control circuit controls the optical encoder to enter a rest mode, and selectively stops providing power to a part of the elements disposed in the optical encoder. Next, return to step S**401** for continuing capturing the images and detecting the current operating state of the optical encoder.

[0048] In step S**405**, the control circuit controls the optical encoder to enter an active mode, and provides power to each element disposed in the optical encoder. Next, return to step S**401** for continuing capturing the images and detecting the current operating state of the optical encoder.

[0049] Notably, in the exemplary embodiment, the control circuit controls the optical encoder to enter the rest mode only when the control circuit receives the first, second determining signal with logic high level and the third determining signal with logic low level. However, the present disclosure is not limited thereto. Those skilled in the art can design the combination of the first, second and the third determining signals to determine other types of abnormal state.

[0050] Please refer to FIG. **5**. FIG. **5** shows a flow diagram of a work mode control method for an optical encoder of another embodiment of the present disclosure. The work mode control method provided in FIG. **5** is also suitable for the optical encoder as mentioned above. In step S**501**, an image sensing array of the optical encoder captures an image once every capturing interval, and transmits the captured image to a determining circuit of the optical encoder. In step S**502**, the determining circuit determines a shutter time, an average brightness and an image quality in response to the images, and generates first, second and third determining signals.

[0051] In step S**503**, a control circuit adjusts a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality. If the first, second determining signals are with logic high level and the third determining signal with logic low level, the control circuit determines the optical encoder is in an abnormal state now, such as the turtle mode shown in FIG. **2**, and then step S**404** is executed for further confirming an operating state of the optical encoder. Conversely, if the first determining signal is not logic high level, the second determining signal is not logic high level and the third determining signal is not logic low level, step S**507** is executed.

[0052] In step S**504**, the determining circuit compares the images to obtain a peak value and a valley value of a brightness of an environmental light, and further calculates a peak-to-valley value of the environmental light. In step S**505**, the control circuit receives the peak-to-valley value, and determines whether the peak-to-valley value exceed a preset region (such as the preset region shown in FIG. **3**). If the peak-to-valley value exceeds the preset region, proceed to step S**506**. If the peak-to-valley value does not exceed the preset region, proceed to step S**507**.

[0053] In step S**506**, the control circuit controls the optical encoder to enter a rest mode, and selectively stops providing power to a part of the elements disposed in the optical encoder. Next, return to step S**501** for continuing capturing the images and detecting the current operating state of the optical encoder.

[0054] In step S**507**, the control circuit controls the optical encoder to enter an active mode, and provides power to each element disposed in the optical encoder. Next, return to step S**501** for continuing capturing the images and detecting the current operating state of the optical encoder.

[0055] In summary, the work mode control method and the optical encoder using the same provided by the instant disclosure can accurately determine the operating state of the optical encoder. As the optical encoder is put in the abnormal state, the optical encoder is switched to the rest mode to save power.

[0056] The above-mentioned descriptions represent merely the exemplary embodiment of the present disclosure, without any intention to limit the scope of the present disclosure thereto. Various equivalent changes, alterations or modifications based on the claims of present disclosure are all consequently viewed as being embraced by the scope of the present disclosure.

What is claimed is:

1. A work mode control method for an optical encoder, comprising the steps of:

(a): capturing an image once every capturing interval;

(b): determining a shutter time, an average brightness and an image quality in response to the images, wherein the shutter time is associated with a time of the optical encoder to capture the images, the average brightness is associated with a brightness of environmental light sensed by the optical encoder, and the image quality is associated with clarity of the images;

(c): adjusting a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality;

(d): controlling the optical encoder to enter a rest mode when the shutter time is higher than a first threshold, the average brightness is higher than a second threshold, and the image quality is lower than a third threshold.

2. The work mode control method according to claim **1**, wherein the work mode control method further comprises the steps of:

(e): comparing the images to obtain a peak-to-valley value of the environmental light;

(f): controlling the optical encoder to ender the rest mode if the peak-to-valley value exceeds a preset region.

3. The work mode control method according to claim **1**, wherein when the optical encoder is in an abnormal state, the shutter time is higher than the first threshold, the average brightness is higher than the second threshold, and the image quality is lower than the third threshold, wherein an image sensing array of the optical encoder is directly irradiated by the environmental light when the optical encoder is in the abnormal state.

4. The work mode control method according to claim **3**, wherein when the optical encoder is in the abnormal state,

the images captured by the image sensing array are fuzzy, and the image quality decreases.

5. The work mode control method according to claim **3**, wherein when the optical encoder is in the abnormal state, the environmental light directly irradiates the image sensing array, such that the optical encoder increases the shutter time, and the average brightness sensed by the image sensing array increases.

6. An optical encoder, comprising:

an image sensing array, configured for operatively capturing an image once every capturing interval;

a determining circuit, coupled to the image sensing array, configured for operatively receiving the images and determining a shutter time, an average brightness and an image quality in response to the images, wherein the shutter time is associated with a time of the optical encoder to capture the images, the average brightness is associated with a brightness of environmental light sensed by the optical encoder, and the image quality is associated with clarity of the images; and

a control circuit, coupled to the determining circuit, configured for operatively adjusting a work mode of the optical encoder in response to the shutter time, the average brightness and the image quality;

wherein the control circuit controls the optical encoder to ender a rest mode when the shutter time is higher than a first threshold, the average brightness is higher than a second threshold, and the image quality is lower than a third threshold.

7. The optical encoder according to claim **6**, wherein the determining circuit compares the images to obtain a peak-to-valley value of the environmental light, and the control circuit controls the optical encoder to enter the rest mode if the peak-to-valley value exceeds a preset region.

8. The optical encoder according to claim **6**, wherein when the optical encoder is in an abnormal state, the shutter time is higher than the first threshold, the average brightness is higher than the second threshold, and the image quality is lower than the third threshold, wherein an image sensing array of the optical encoder is directly irradiated by the environmental light when the optical encoder is in the abnormal state.

9. The optical encoder according to claim **8**, wherein when the optical encoder is in the abnormal state, the images captured by the image sensing array are fuzzy, and the image quality decreases.

10. The optical encoder according to claim **8**, wherein when the optical encoder is in the abnormal state, the environmental light directly irradiates the image sensing array, such that the optical encoder increases the shutter time, and the average brightness sensed by the image sensing array increases.

* * * * *