

A DATA LOGGING SYSTEM AND METHOD THEREOF

FIELD OF INVENTION

The invention relates to the field of data logging. More particularly, the invention relates to a data logging system.

BACKGROUND OF THE INVENTION

A data logging system is a system that monitors activities and environmental parameters of a specific location with the aid of instruments or sensors. In the data logging system, a data logging device is used to collect data related to the activities or environmental parameters. Over the years, data logging systems have become increasingly common in the agricultural industry to achieve precision agriculture. For example, when in use, a data logging device can be held by an agricultural worker while performing an agricultural activity in an agricultural field to record the agricultural activity performed by the agricultural worker. This ensures that various aspects of agricultural management, such as quality and quantity of the agricultural activity performed, condition of the agricultural field, and weather conditions, can be monitored to improve yield and reduce inputs and cost.

Over the years, various data logging systems have been developed. For instance, US Patent Application Publication No. US20130275187A1 discloses a work measurement system comprising a handheld electronic device and a server that are communicatively coupled to each other. Accordingly, the handheld electronic device is designed to receive an asset record and input data related to a worker's various activity readings, which are collected through sensors such as a global positioning system sensor, a camera, or an accelerometer. Meanwhile, the server is responsible for receiving the asset record and activity readings from the handheld electronic device for subsequent

review and analysis.

The handheld electronic device of the work measurement system may have high power consumption due to the data transmission and interaction with the server. However, the handheld electronic device has a limited capacity of power supply, which limits the operating duration before having to recharge the power supply. Therefore, it would be desirable to provide a data logging system that overcomes the aforementioned problem. This invention provides a solution to the problem.

SUMMARY OF INVENTION

One objective of the invention is to provide a data logging system having a data logging device with improved power optimization and transceiving efficiency. Particularly, the data logging device comprises a communication module configured to switch the data logging device between a plurality of communication protocols based on a current operating condition of the data logging device.

In a first aspect of the invention, there is provided a data logging system for monitoring work activity, the data logging system comprises a plurality of sensors for collecting sensor data; a data logging device comprises a geographical positioning sensing component for collecting location data of the data logging device; a processing module for processing the sensor data and the location data; and a transceiver configured to receive the sensor data and transmit the processed data, from the processing module, over a wireless network communication at a predetermined time interval, a random time interval, or a combination thereof, and a server configured to receive the processed data from the transceiver over the wireless network communication and analyse the processed data, wherein the data logging device further comprises a device management module configured to determine a current operating condition of the data logging device and switch the data logging device between a plurality of

communication modules to optimize power consumption and data transceiving efficiency of the data logging device based on the current operating condition.

Preferably, the sensors include a set of environmental sensors, a set of work activity sensors, or a combination thereof.

Preferably, the environmental sensors include a temperature sensor, a soil moisture sensor, a soil nutrient sensor, a soil pH sensor, a rain sensor, an air humidity sensor, a weather sensor, or any combination thereof.

Preferably, the work activity sensors include an accelerometer, a gyroscope, a mechanical actuator, or any combination thereof.

Preferably, the processing module is configured to encrypt and/or compress the processed data for storage or transmission to the server.

Preferably, the server is configured to analyse the processed data using one or more algorithms to determine a pathway travelled by the worker and information of the work activity performed by the worker along the pathway.

Preferably, the server is further configured to predict missing sensor data, missing location data, or a combination thereof of the data logging device along the pathway when receiving the sensor data between previously collected location data points.

Preferably, the wireless network communication is a low power long-range wireless network communication which comprises a plurality of gateways that are connected to one another via a long-range wireless protocol.

Preferably, the gateways comprises a plurality of primary gateways, secondary

gateways, and mobile gateways.

Preferably, the server is further configured to establish a coverage of a predefined operational area that bounds the data logging device therewithin such that the sensor data and the location data are not collected by the data logging device when the data logging device is not within the coverage of the predefined operational area.

Preferably, the communication modules include a high power communication module and a low power communication module.

Preferably, the device management module further configured to switch the data logging device between sleep mode after a predetermined period of inactivity and active mode when the data logging device is in use.

Preferably, the data logging system further comprises a wireless charging platform for charging the data logging device.

Preferably, the processing module is further configured to synchronise the sensor data and/or the processed data with the server via a data synchronisation algorithm by transmitting the sensor data and/or processed data to the server when the data logging device is being charged at the wireless charging platform, when the data logging device is in the sleep mode, or a combination thereof.

Preferably, the processing module is further configured to initiate a new data logging session when the data logging device is removed from the wireless charging platform.

Preferably, the data logging device further comprises a display module for displaying a power status of the data logging device, a battery level of the data logging device, a location of the data logging device, or any combination thereof.

Preferably, the data logging system further comprises a mobile device in communication with the data logging device for storing the sensor data received from the data logging device and transmitting the sensor data to the server over the wireless network communication.

In a second aspect of the invention, there is provided a method for determining a current operating condition and switching communication modules of the data logging device, the method comprising the steps of determining, by the device management module, the power status of the data logging device; computing, by the device management module, a travel speed of the data logging device based on location data at an interval of time; comparing, by the device management module, the travel speed with a predetermined travel speed; switching, by the device management module, the data logging device between the plurality of communication modules based on the power status and/or the travel speed of the data logging device.

Preferably, the device management module switches the data logging device between a high power communication module for high frequency transmission of the sensor data and high power consumption when the data logging device is receiving power from a power source and/or the travel speed is higher than the predetermined travel speed, and a low power communication module for low frequency transmission of the sensor data and low power consumption when the data logging device is not receiving power from the power source and/or the travel speed is lower than the predetermined travel speed.

One skilled in the art will readily appreciate that the invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiments described herein are not intended as limitations on the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawing the preferred embodiments from an inspection of which when considered in connection with the following description, the invention, its construction and operation and many of its advantages would be readily understood and appreciated.

- Fig. 1 is a schematic diagram illustrating a data logging system.
- Fig. 2 illustrates types of sensors employed in the data logging system.
- Fig. 3 illustrates placements of the sensor and a data logging device.
- Fig. 4 is a schematic diagram illustrating components of a data logging device.
- Fig. 5 is a schematic diagram illustrating components of a server of the data logging system.
- Fig. 6 is a schematic diagram illustrating a secondary gateway of the data logging system.
- Fig. 7 is a schematic diagram illustrating a primary gateway of the data logging system.
- Fig. 8 is a schematic diagram illustrating a wireless charging platform of the data logging system.

DETAILED DESCRIPTION OF THE INVENTION

The invention will now be described in greater detail, by way of example, with reference to the drawings.

Fig. 1 illustrates a preferred embodiment of a data logging system (100) for monitoring work activity. Although the data logging system (100) is presented as an example of its use in the agricultural industry to monitor worker activity in a field, it is important to note that the data logging system (100) can have a much versatile applications and can be utilized in various other industries. Generally, the data logging system (100) comprises a plurality of sensors (101), a data logging device (200) in communication with the sensors (101), and a server (300) in communication with the data logging device (200).

Preferably, the sensors (101) can be but not limited to a set of environmental sensors, a set of work activity sensors, or a combination thereof, as illustrated in Fig. 2. The environmental sensors collect sensor data related to environmental conditions of a work location whereas the work activity sensors collect sensor data related to the work activity within the work location. The environmental sensors can be pre-distributed within any part of the work location. By way of example, the environmental sensors can include but not limited to a temperature sensor, a soil moisture sensor, a soil pH sensor, soil nutrient sensors, a rain sensor, an air humidity sensor, a weather sensor, or any combination thereof. Preferably, the soil nutrient sensors can be a soil NPK sensor that measures nitrogen, phosphorus, and potassium contents in soil to determine fertility of the soil.

On the other hand, the work activity sensors can be attached to the worker and/or coupled to an equipment (104) associated with the worker, as illustrated in Fig. 3. Alternatively, the work activity sensors can be an in-built sensors of the equipment (104). Optionally, the work activity sensors can be coupled or embedded in wearable

accessory such as a wristband. By way of example, the work activity sensors can include but not limited to an accelerometer, a gyroscope, or a combination thereof. The work activity sensors aim to collect sensor data related to the work activity based on motion and movement of the worker and/or the equipment (104) associated with the worker. Preferably, the work activity can include but not limited to harvesting, fertilizing, and weed removal. In one specific example, the work activity sensors are coupled to a sickle such that sensor data can be collected based on harvesting motion of the sickle performed by the worker. Furthermore, the work activity sensor can be a mechanical actuator designed to be triggered by the worker in various ways that correspond to a work activity assigned to the worker. Preferably, the mechanical actuator takes the form of a button that can be pressed by the worker in different ways to collect data related to the work activity. When in use, the worker triggers the mechanical actuator in a manner that corresponds to an assigned work activity such as a single press, double press, short press, long press, or press and hold for at least a predetermined period. Additionally, the sensor (101) may further include a force sensor such as a load cell coupled to the equipment (104) for collecting sensor data related to applied force during work activity. Advantageously, the applied force collected by the force sensor in addition to the work activity sensors ensures that the work activity is appropriately performed by the worker.

Fig. 4 illustrates a preferred embodiment of the data logging device (200). The data logging device (200) is preferably a handheld electronic device held by the worker such that environmental conditions of the work location and the work activity performed by the worker within the work location can be monitored. Preferably, the data logging device (200) generally comprises a geographical position sensing component (201), a processing module (202), and a transceiver (203). Alternatively, the data logging device (200) may comprise input means for collecting input data directly from the data logging device (200). Preferably, the input means can be another accelerometer (205). Optionally, the data logging device (200) may further comprise a camera module (210)

for collecting the input data by taking pictures or videos of the worker's surrounding.

The data logging device (200) is equipped with the geographical position sensing component (201) that is responsible for collecting location data of the data logging device (200). For instance, the geographical position sensing component (201) may comprise a global positioning system sensor that can be configured to periodically or continuously collect the location data of the data logging device (200) within the work location. An example of this is setting the geographical position sensing component (201) to collect the location data every 5 seconds. This feature is particularly advantageous in reducing power consumption of the data logging device (200) or the workload of the processing module (202) when performing work activities that do not require continuous location tracking, such as oil palm fresh fruit bunch cutting, whereby the worker remains at the same location for a significant period of time.

The processing module (202) is responsible to process the sensor data and location data collected. Preferably, the processing module (202) receives the sensor data from the transceiver (203) and the location data from the geographical position sensing component (201) for processing into processed data. For example, the processing module (202) can be a microcontroller. Ideally, the processing module (202) is designed to encrypt and/or compress the sensor data and the location data to ensure data confidentiality and security and/or to reduce size of the sensor data and the location data. The processing module (202) also performs error correction on the location data during the encryption and/or compression processes to guarantee the integrity of the processed data. The data logging device (200) also has a memory module (207), and is responsible for storing the processed data.

The transceiver (203) is an essential component that enables the data logging device (200) to receive the sensor data from the sensors (101) and to transmit the processed data to the server (300) over a wireless network communication at a predetermined time

interval, a random time interval, or a combination thereof. The transceiver (203) is operably connected to the processing module (202) to prepare for the transmission of the processed data to the server (300). The aforementioned time intervals of data transmission are an important aspect of the data logging device's (200) operation. Preferably, the predetermined time interval can be set to between 5 seconds to 10 seconds or any other interval that is deemed suitable for the particular application. The aforementioned time intervals ensure that the server (300) receives the data in a timely manner and is updated on a regular basis.

In the preferred embodiment of the invention, the data logging device (200) further comprises a device management module (209) configured to determine a current operating condition of the data logging device (200). The device management module (209) is also configured to switch the data logging device (200) between a plurality of communication modules (204) based on the current operating condition of the data logging device (200). Advantageously, the device management module (209) optimizes power consumption of the data logging device (200) based on the current operating condition. Furthermore, the device management module (209) optimizes the efficiency of receiving the sensor data from the sensors (101) and transmitting the processed data to the server (300) based on the current operating condition.

Preferably, the current operating condition of the data logging device (200) can include but not limited to power status of the data logging device (200), travel speed of the data logging device (200), and battery level of the data logging device (200). More preferably, the current operating condition of the data logging device (200) includes the power status of the data logging device (200) and the travel speed of the data logging device (200). The power status includes a charging status in which the data logging device (200) is receiving power from a power source and an uncharged status in which the data logging device (200) is not receiving power from the power source. The travel speed refers to a distance travelled by the data logging device (200) within an interval

of time. The battery level refers to remaining capacity of a rechargeable battery of the data logging device (200), in which a high battery level indicates that the remaining capacity of the rechargeable battery is above a predetermined battery level, whereas a low battery level indicates that the remaining capacity of the rechargeable battery is below the predetermined battery level. Preferably, the predetermined battery level can be configurable.

The communication modules (204) can include but not limited to a high power communication module and a low power communication module. When the data logging device (200) is switched to the high power communication module, the data logging device (200) operates at a high frequency and a high power consumption state for an increased reception rate of the sensor data and transmission rate of the processed data. On the contrary, when the data logging device (200) is switched to the low power communication module, the data logging device (200) operates at a low frequency and a low power consumption state for a reduced reception rate of the sensor data and transmission rate of the processed data. Preferably, the high power communication module includes a WiFi communication module (204b) or a high frequency long-range (LoRa) wireless communication module (204a). The high power communication module allows the data logging device (200) to operate at an increased spreading factor and a high power consumption state for an increased reception rate of the sensor data and transmission rate of the processed data over an extended range. On the other hand, the low power communication module preferably includes a Bluetooth communication module (204c) or a low frequency LoRa wireless communication module (204a). The low power communication module allows the data logging device (200) to operate at a decreased spreading factor and a relatively low power consumption state for a reduced reception rate of the sensor data and transmission rate of the processed data over a reduced range.

When in use, the device management module (209) determines the power status of the

data logging device (200) by detecting whether the rechargeable battery is charging or uncharged. The device management module (209) also computes the travel speed of the data logging device (200) based on the location data at the interval of time. The interval of time can preferably be a time interval at which the geographical position sensing component (201) collects the location data of the data logging device (200). Preferably, the travel speed can be computed based on a distance travelled between two consecutive location data at the interval of time. The travel speed is preferably computed on a real-time basis such that the device management module (209) is updated with the travel speed of the data logging device (200) on a real-time basis. Additionally, the accelerometer (205) of the data logging device (200) can obtain the input data related to the travel speed of the data logging device (200) to ensure the accuracy of the travel speed computed by the device management module (209). Subsequently, the device management module (209) compares the travel speed with a predetermined travel speed. Then, the device management module (209) switches the data logging device (200) between the communication modules (204) based on the power status and/or the travel speed of the data logging device (200).

After determining the current operating condition of the data logging device (200), the device management module (209), based on the current operating condition, decides to switch between the high power communication module when the data logging device (200) is receiving power from a power source and/or the travel speed is higher than the predetermined travel speed, and a low power communication module when the data logging device (200) is not receiving power from the power source and/or the travel speed is lower than the predetermined travel speed. For instance, the device management module (209) switches the data logging device (200) to the high power communication module when the data logging device (200) is receiving power from a power outlet of a vehicle (103) in the work location.

Additionally, the vehicle (103) travels from one location to another location to perform

the work activity at a shorter time interval as compared to the worker who travels by foot. By way of example, the vehicle (103) travels from one location to another location to collect the harvested crops at a shorter time interval as compared the worker who is harvesting the crops. Therefore, when the data logging device (200) is associated with the vehicle (103), the data logging device (200) is at a higher travel speed as compared to the data logging device (200) associated with the worker. As a result, the data logging device (200) associated with the vehicle (103) receives the sensor data more frequently than the data logging device (200) associated the worker due to larger area covered by the vehicle (103). Advantageously, the device management module (209) switches the data logging device (200) associated with the vehicle (103) to the high power communication module for an increased reception rate of the sensor data from the sensors (101) and transmission rate of the processed data to the server (300) for analysis. Preferably, the communication module (204) switches the data logging device (200) to the lower power communication module when the travel speed of the data logging device (200) is lower than the predetermined travel speed or when the data logging device (200) stops moving.

In addition, the device management module (209) can switch the data logging device (200) between the high power communication module when the data logging device (200) is at the high battery level and the low power communication module when the data logging device (200) is at the low battery level. Advantageously, the device management module (209) optimizes power consumption and data transceiving efficiency of the data logging device (200) such that the power of the data logging device (200) is sufficient to complete at least one data logging session.

Preferably, the transceiver (203) of the data logging device (200) is in a combination of a LoRa transceiver, a WiFi transceiver, and a Bluetooth transceiver for receiving sensor data based on the corresponding communication modules (204). By way of example, when the device management module (209) switches the data logging device (200) to

the high power communication module that employs the WiFi communication module (204b), the sensor data is received by the data logging device (200) and transmitted to the server (300) using the WiFi transceiver.

The server (300) is configured to receive the processed data from the transceiver (203) over the wireless network communication. The server (300) can be a local or a cloud-based portal service, operated by one or more computers and any known devices or group of devices to provide sufficient capacity for storing data. The server (300) is preferably stored with plurality sets of computer-implementable instructions to perform and automate the different operations, and the different sets of instructions are performed by software or hardware-based modules of the server. Referring to Fig. 5, such modules may preferably include a data receiving and filtering module (301), an incoming data frame processing module (302), a time-stamping module (303), an analytics module (304), a plurality of databases (305), and an application programming interface (API) module (306).

Upon receiving the processed data from the data logging device (200), the data receiving and filtering module (301) performs a deduplication process to remove duplicated or redundant data. Then, the incoming data frame processing module (302) decodes and decompresses the processed data. Preferably, the server (300) is configured to time-stamp the processed data via the time-stamping module (303) after the decoding process and decompression process to determine a pathway travelled by the worker and information of the work activity performed by the worker along the pathway. By way of example, the information of the work activity can be counts of the work activity performed by the worker for countable work activity such as crop harvesting. Alternatively, the information of the work activity can be markings or indications of the work activity performed by the worker for uncountable work activity such as weed removal. Then, the analytics module (304) is configured to predict missing sensor data, missing location data, or a combination thereof of the data logging device (200) along

the pathway when receiving the sensor data between previously collected location data points. For example, when the geographical position sensing component (201) collects the location data of the data logging device (200) at $t_1 = 5$ s and $t_2 = 10$ s, the server (300) can predict the location of the data logging device (200) when the sensor data is received by the processing module (202) at any time between t_1 and t_2 . By way of example, the analytics module (304) calculates the location of the data logging device (200) by interpolating the data between t_1 and t_2 with reference to time spent between two consecutive location data collected and historical data. Alternatively, the analytics module (304) may employ artificial intelligence in predicting the missing data of the data logging device (200) along the pathway and the work information of the work activity performed by the worker. By way of example, the artificial intelligence can employ any machine learning model such as a neural network to predict the missing data of the data logging device (200) and the work information based on weightages obtained from the location data and the sensor data. Alternatively, the artificial intelligence may predict position and/or trajectory of the data logging device (200) at a future time point based on the historical data.

Additionally, the artificial intelligence can be employed to improve the data logging system (100) in various aspects such as work activity recognition, anomaly detection in work activity, predictive maintenance, and resource optimization. In work activity recognition, the data logging device (200) may collect the work activity data from a sequence of button presses input by the worker via the mechanical actuator. The work activity data can then be analysed by the artificial intelligence in the analytics module (304) using machine learning algorithms such as Support Vector Machines (SVM), Random Forests, and Gradient Boosting Machines (GBM) to determine the types of work activity. The artificial intelligence can learn to recognize patterns correspond to different types of work activity by training with labelled data representing each role and/or work activity assigned to the worker. Besides, machine learning algorithms such as SVM, Random Forest, an ensemble learning algorithms based on decision trees,

Hidden Markov Models can be used to model accelerometer data to recognize types of work activity, such as cutting a fresh fruit bunch stalk.

Anomaly detection techniques such as clustering and time-series analysis can be used by the artificial intelligence in detecting anomaly in work activity. Particularly, the artificial intelligence may employ algorithms such as k-means, Gaussian Mixture Models, and Self-Organizing Maps to detect deviations from expected work motions and/or movements based on the types of work activity. By establishing a baseline using historical data stored in the databases (305), the artificial intelligence can identify outliers and suggest corrective actions based on the deviations. Furthermore, reinforcement learning techniques can be used by the artificial intelligence to enhance its ability to suggest the corrective actions to the worker based on the deviations. The artificial intelligence can learn from errors and improve its models over time through offering feedback and rewards based on the accuracy of the suggestions. By way of example, the reinforcement learning techniques such as Q-learning, Deep Q-Networks (DQN), and Proximal Policy Optimization can be used.

Preferably, the artificial intelligence may perform predictive maintenance. Particularly, the artificial intelligence can use supervised learning algorithms such as SVM, Random Forests, and GBM to determine conditions of the data logging system (100). Preferably, the artificial intelligence may perform the predictive maintenance using the time-series analysis such as Autoregressive Integrated Moving Average and Long Short-Term Memory networks via the abovementioned supervised learning algorithms. The predictive maintenance is preferably performed based on analysis of factor such as usage patterns, environmental conditions, and historical maintenance records that are stored in the databases (305). Advantageously, the artificial intelligence can proactively alert and recommend maintenance tasks to ensure optimum condition of the data logging system (100).

The artificial intelligence may also perform analysis to optimize resource usage using techniques such as Genetic Algorithms technique and Linear Programming technique. By way of example, the Genetic Algorithms technique can include Genetic Programming and Evolutionary Strategies, whereas the Linear Programming technique can include Simplex Method and Interior Point Method. Moreover, the reinforcement learning techniques can be employed such that the artificial intelligence can gradually adapt itself according to the feedback, whereas Association Rule Mining can be used to discover correlations and relationships between resource usage patterns. By way of example, the reinforcement learning techniques can include the Q-learning and the DQN.

In addition, the analytics module (304) reviews the analysed processed data. Particularly, the analytics module (304) can be configured to generate a report of the analysis, provide alert in event of detecting anomalies during analysis, and monitoring the transmission of the processed data. Furthermore, the databases (305) are provided for storing the sensor data and/or the processed data received from the data logging device (200), the report generated by the analytics module (304), analysed processed data obtained from the analytics module (304), and the historical data. Additionally, the database (305) can also store staffs' and customers' information. Moreover, the API module (306) allows authorized devices to communicate with the server (300) to retrieve information from the databases (305).

Preferably, the wireless network communication comprises a plurality of gateways (400, 500) that are connected to one another via a wireless protocol. Preferably, the wireless protocol may include LoRa radio, Bluetooth Low Energy (BLE), or radio frequency identification. More preferably, the wireless protocol is LoRa radio. Nonetheless, the wireless protocol can be replaced by other wireless protocols such as Long-Term Evolution (LTE) cloud, Code Division Multiple Access (CDMA) and its derivatives, Enhanced Data Rates for GSM Evolution (EDGE), 3G protocol, High

Speed Packet Access (HSPA), 4G protocol, 5G protocol and the like, in accordance to the advancement of wireless technology with time.

In one embodiment, the gateways (400, 500) can be categorised into two groups, namely primary gateways (500) and secondary gateways (400). The roles of the primary gateways (500) and the secondary gateways (400) are interchangeable so that the wireless network communication can continue to function optimally even if one set of the gateways (400, 500) malfunctions or requires maintenance. Preferably, the primary gateways (500) can be located closer to a base station whereas the secondary gateways (400) can be located further from the base station and scattered across the work location. The base station can be a central communication point whereby the processed data is received by the servers (300) for analysis. The secondary gateways (400) receive the processed data from nearby data logging devices (200) and communicate with the primary gateways (500). Alternatively, the gateways (400, 500) can be powered by renewable energy sources such as solar energy, biomass, hydro power, geothermal, wind energy, and etc. By way of example, the gateways (400, 500) are connected to solar panels.

Referring to Fig. 6, each of the secondary gateways (400) preferably comprises a secondary data frame database (401), which temporarily stores the processed data received from nearby data logging devices (200). Additionally, each of the secondary gateways (400) is equipped with a secondary packet forwarder module (402) for forwarding the processed data to the server (300). The secondary gateways (400) can also take over the role of the primary gateway (500) and communicate directly with the server (300) in an event of primary gateway (500) failure. Furthermore, the secondary gateway (400) preferably switches between a plurality of secondary gateway communication modules (403) corresponding to the communication modules (204) when receiving the processed data from the data logging device (200). Preferably, the secondary gateway communication modules (403) includes a secondary gateway LoRa

wireless module (403a), a secondary gateway WiFi module (403b), and a secondary gateway Bluetooth module (403c).

On the other hand, the primary gateways (500) receive the processed data from the nearby data logging devices (200) and the secondary gateways (400), and subsequently communicates with the server (300) to transmit the processed data to the server (300). The primary gateways (500) can be wiredly or wirelessly connected to the server (300).

Referring to Fig. 7, each of the primary gateways (500) preferably comprises a database (501), a gateway server module (502), a device communication module (503), a primary packet forwarder module (504), a primary data frame database (505), and a primary gateway communication module (506). Preferably, the in-memory database (501) stores data cache, whereas the gateway server module (502) acts as an intermediary that allows the primary gateways (500) to receive the processed data from nearby data logging devices (300) and the secondary gateways (400) and communicate with the server (300). By way of example, the gateway server module (502) may employ a LoRaWAN network server. Preferably, the primary data frame database (505) temporarily stores the processed data received from nearby data logging devices (200) and the secondary gateways (400). Additionally, the primary packet forwarder module (504) forwards the processed data to the server (300). Furthermore, the device communication module (503) allows the primary gateway (500) to communicate with the data logging device (200) to ensure integrity of the processed data received and transmits the processed data to the server (300). The primary gateway (500) preferably switches between a plurality of primary gateway communication modules (506) corresponding to the communication modules (204) when receiving the processed data from the data logging device (200). Preferably, the primary gateway communication modules (506) includes a primary gateway LoRa wireless communication module (506a), a primary gateway WiFi communication module (506b), and a primary gateway Bluetooth module (506c).

Preferably, the communication module (204) employs an exponential backoff algorithm in transmitting the processed data from the data logging device (200) to the secondary gateways (400) or the primary gateways (500). The exponential backoff algorithm uses feedback to reduce the transmission rate of the processed data to gradually find an acceptable transmission rate. Particularly, priority frames of the processed data are prioritized during transmission to improve data transmission rate. Advantageously, the exponential backoff algorithm increases likelihood of the processed data being received by the server (300). Furthermore, the exponential backoff algorithm reduces likelihood of data loss during transmission in an event of communication error.

In addition, the gateways (400, 500) can be located on any type of vehicle (103) in the work location such as a tractor and an unmanned aerial vehicle, which serves as a mobile gateway that receives the processed data from nearby data logging devices (200) and transmits the processed data to the primary gateway (500) and/or the server (300). Preferably, the mobile gateway may comprise modules similar to that of the primary gateway (500) and/or the secondary gateway (400). Advantageously, the mobile gateway can preferably assume the roles of the primary gateways (500) and/or the secondary gateways (400) where necessary such that the wireless network communication can continue to function optimally even if one set of the gateways (400, 500) malfunctions or requires maintenance. Additionally, the mobile gateway receives the processed data from nearby data logging devices (200) at a closer proximity as compared to the secondary gateways (400) and/or the primary gateways (500) which are stationary. This minimizes packet loss during transmission of processed data from the data logging device (200) to the secondary gateway (400) and/or the primary gateway (500).

The server (300) is further configured to establish a coverage of a predefined operational area that bounds the data logging device (200) therewithin such that the

sensor data and the location data are not collected by the data logging device (200) when the data logging device (200) is not within the coverage of the predefined operational area. Preferably, the predefined operational area can be the work location. This ensures that the data logging device (200) is only operable in the work location. Advantageously, this prevents collection of irrelevant input data and location data outside the work location that is not related to the work activity. The presence of the irrelevant input data and location data increases the size of the processed data, which adversely affects the data transmission from the gateways (400, 500) to the server (300) and the analysis performed by the server (300). By way of example, the server (300) may establish a virtual perimeter that defines the coverage of the predefined operational area via a geofencing technique, whereby the data logging device (200) that is within the virtual perimeter are within the coverage of the predefined operational area.

Furthermore, the data logging device (200) preferably includes an audio signal module (206) as illustrated in Fig. 4. The audio signal module (206) provides the worker with an audio notification when the processing module (202) receives sensor data from the work activity sensors. Additionally, the audio signal module (206) provides the worker with the audio notification when the data logging device (200) is connected or disconnected from the wireless network communication. Moreover, the audio signal module (206) provides audio signal to assist the worker in searching for the data logging device (200) that is lost in the work location. By way of example, the worker can notify the server (300) regarding the lost data logging device (200). Subsequently, the server (300) can send a signal to the audio signal module (206) such that the audio signal is released to assist the worker in searching for the lost data logging device (200). The audio signal module (206) may consist of a buzzer or other similar device.

In another embodiment of the invention, the device management module (209) is further configured to switch the data logging device (200) between sleep mode and active mode. Preferably, the device management module (209) switches the data

logging device (200) to the sleep mode after a predetermined period of inactivity. Preferably, the predetermined period of inactivity refers to a duration in which the transceiver (203) does not receive sensor data from the sensors (101). The predetermined period of inactivity is preferably configurable. By way of example, the predetermined period of inactivity can be 15 minutes. On the other hand, the device management module (209) preferably switches the data logging device (200) to the active mode from the sleep mode when the data logging device (200) is in use. Preferably, upon receiving the sensor data from the sensors (101) during the sleep mode, the device management module (209) switches the data logging device (200) to the active mode from the sleep mode. Advantageously, the device management module (209) conserves battery usage of the data logging device (200). .

In the other embodiment of the invention, the data logging system (200) further comprises a wireless charging platform (600) for charging the rechargeable battery of the data logging device (200). The rechargeable battery supplies power to the components of the data logging device (200), whereas the wireless charging platform (600) charges a wireless charging module (208) of the data logging device (200) by supplying electricity to the rechargeable battery. Referring to Fig. 8, the wireless charging platform (600) preferably comprises a cabinet body (601), a wireless charging pad for charging the wireless charging module (208) of the data logging device (200), and a support member (603) that secures placement of the data logging device (200) in the wireless charging platform (600). Preferably, the rechargeable battery can be a rechargeable alkaline battery or a lithium-ion battery. In addition, the audio signal module (206) provides audio notifications to the worker when the battery level is low or when the data logging device (200) is connected to the wireless charging platform (600) for charging.

Furthermore, the processing module (202) is further configured to synchronise the sensor data and/or the processed data with the server (300) via a data synchronisation

algorithm by transmitting the sensor data and/or the processed data to the server (300) when the data logging device (200) is being charged at the wireless charging platform (600). Particularly, the processing module (202) identifies the sensor data, the location data, the processed data, or any combination thereof, which are missing from the server (300) and then uploads the identified missing data to the server (300) via the data synchronization algorithm when the data logging device (200) is being charged at the wireless charging platform (600). Additionally, the sensor data and/or processed data can preferably be synchronised with the server (300) when the data logging device (200) is switched to the sleep mode. Packet loss may occur during data transmission from the gateways (400, 500) to the server (300) over the wireless network communication, which leads to the missing sensor data and the missing location data. Consequently, the missing sensor data and the missing location data can adversely affect the analysis performed by the server (300). Advantageously, the data synchronization algorithm ensures that the server (300) receives the entirety of the processed data for analysis. When the data logging device (200) is being charged at the wireless charging platform (600), the device management module (209) switches the data logging device (200) to the high power communication module. Advantageously, this allows the processed data to be transmitted from the memory module (207) to the server (300) over the wireless network communication at an increased transmission rate during the data synchronisation process. On the other hand, when the data logging device (200) is switched to the sleep mode, the device management module (209) switches the data logging device (200) to the low power communication module. Advantageously, this allows the processed data to be transmitted from the memory module (207) to the server (300) over the wireless network communication at a reduced transmission rate during the data synchronisation process such that battery usage is conserved.

Preferably, the processing module (202) is further configured to initiate a new data logging session when the data logging device (202) is removed from the wireless

charging platform (600). Additionally, the memory module (207) is further configured to temporarily store the processed data of previous data logging sessions. In addition, the audio signal module (206) provides notifications when the data synchronisation process is initiated.

Preferably, the wireless charging platform (600) further comprises a backup gateway that functions as per the gateways (400, 500) mentioned earlier to transmit the processed data to the server (300) when the data logging device (200) is docked in the wireless charging platform (600) for charging. Additionally, the wireless charging platform (600) further comprises a solar power generation assembly for powering the wireless charging platform (600) to charge the data logging device (200). Advantageously, the solar power generation assembly serves as a secondary power supply of the wireless charging platform (600) in the event of power outage.

Preferably, the analytics module (304) in the server (300) monitors health statuses of the data logging device (200), the backup gateways, and the wireless charging platform (600). Additionally, the analytics module is further configured to generate a report of the health statuses.

Additionally, the data logging device (200) further comprises a display module for displaying a power status of the data logging device (200), a battery level of the data logging device (200), a location of the data logging device (200), or any combination thereof. The display module can further display a current location of the lost data logging device (200) based on the location data.

The data logging system (100) further comprises a mobile device (102) in communication with the data logging device (200). The mobile device (102) stores the sensor data received from the data logging device (200) and transmits the sensor data to the server (300) over the wireless network communication. The mobile device (102)

can be a smartphone, a tablet, a laptop, or the like. Preferably, the mobile device (102) is a smartphone. When the equipment (104) associated with the worker and/or the worker leave the work location, the work activity sensors and the data logging device (200) are no longer within the coverage of the predefined operational area. For example, when the worker and a collecting bin loaded with harvested crops leave the work location to a processing mill, the data logging device (200) is no longer within the coverage of the predefined operational area. As a result, the sensor data collected by the data logging device (200) is unable to reach the server (300) due to absence of gateways (400, 500) in proximity. In this situation, the mobile device (102) serves as a temporary gateway to receive the sensor data from the data logging device (200). Advantageously, the mobile device (102) allows the sensor data to be transmitted to the server (300) by directly communicating with the server (300), thereby ensuring a thorough monitoring of the work activity. Additionally, the mobile device (102) is preferably installed with an application that allows communication with the data logging system (100) via a user interface.

The present disclosure includes as contained in the appended claims, as well as that of the foregoing description. Although this invention has been described in its preferred form with a degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangements of parts may be resorted to without departing from the scope of the invention.

CLAIMS

1. A data logging system (100) for monitoring work activity, the data logging system (100) comprises:
 - a plurality of sensors (101) for collecting sensor data; and
 - a data logging device (200) comprising
 - a geographical positioning sensing component (201) for collecting location data of the data logging device (200);
 - a processing module (202) for processing the sensor data and the location data; and
 - a transceiver (203) configured to receive the sensor data and transmit the processed data, from the processing module (202), over a wireless network communication at a predetermined time interval, a random time interval, or a combination thereof, and
 - a server (300) configured to receive the processed data from the transceiver over the wireless network communication and analyse the processed data,
- wherein the data logging device (200) further comprises a device management module (209) configured to determine a current operating condition of the data logging device and switch the data logging device between a plurality of communication modules (204) to optimize power consumption and data transceiving efficiency of the data logging device (200) based on the current operating condition, and
- wherein the device management module (209) switches the data logging device (200) between a high power communication module for high frequency transmission of the sensor data and high power consumption when the data logging device (200) is receiving power from a power source and/or a travel speed of the data logging device (200) is higher than a predetermined travel speed, and a low power communication module for low frequency transmission of the sensor data and low power consumption when the data logging device (200) is not receiving power from the power source and/or the travel speed of the data logging device (200) is lower

than the predetermined travel speed.

2. The data logging system (100) according to claim 1, wherein the sensors (101) include a set of environmental sensors, a set of work activity sensors, or a combination thereof.
3. The data logging system (100) according to claim 2, wherein the environmental sensors include a temperature sensor, a soil moisture sensor, a soil pH sensor, a soil nutrient sensor, a rain sensor, an air humidity sensor, a weather sensor, or any combination thereof.
4. The data logging system (100) according to claim 2, wherein the work activity sensors include an accelerometer, a gyroscope, a mechanical actuator, or any combination thereof.
5. The data logging system (100) according to claim 1, wherein the processing module (202) is configured to encrypt and/or compress the processed data for storage or transmission to the server (300).
6. The data logging system (100) according to claim 1, wherein the server (300) is configured to analyse the processed data using one or more algorithms to determine a pathway travelled by the worker and information of the work activity performed by the worker along the pathway.
7. The data logging system (100) according to claim 6, wherein the server (300) is further configured to predict missing sensor data, missing location data, or a combination thereof of the data logging device (200) along the pathway when receiving the sensor data between previously collected location data points.

8. The data logging system (100) according to claim 1, wherein the wireless network communication is a long-range wireless network communication which comprises a plurality of gateways (400, 500) that are connected to one another via a long-range wireless protocol.
9. The data logging system (100) according to claim 1, wherein the gateways (400, 500) comprises a plurality of primary gateways (500), secondary gateways (400), and mobile gateways.
10. The data logging system (100) according to claim 8, wherein the server (300) is further configured to establish a coverage of a predefined operational area that bounds the data logging device (200) therewithin such that the sensor data and the location data are not collected by the data logging device (200) when the data logging device (200) is not within the coverage of the predefined operational area.
11. The data logging system (100) according to claim 1, wherein the device management module (209) configured to switch the data logging device (200) between sleep mode after a predetermined period of inactivity and active mode when the data logging device (200) is in use.
12. The data logging system (100) according to claim 1, further comprising a wireless charging platform (600) for charging the data logging device (200).
13. The data logging system (100) according to claim 12, wherein the processing module (202) is further configured to synchronise the sensor data and/or the processed data with the server (300) via a data synchronisation algorithm by transmitting the sensor data and/or the processed data to the server (300) when the data logging device (200) is being charged at the wireless charging platform (600), when the data logging device (200) is in the sleep mode, or a combination thereof.

14. The data logging system (100) according to claim 12, wherein the processing module (202) is further configured to initiate a new data logging session when the data logging device (200) is removed from the wireless charging platform (600).
15. The data logging system (100) according to claim 1, wherein the data logging device (200) further comprises a display module for displaying a power status of the data logging device (200), a battery level of the data logging device (200), a location of the data logging device (200), or any combination thereof.
16. The data logging system (100) according to claim 1, further comprising a mobile device (102) in communication with the data logging device (200) for storing the sensor data received from the data logging device (200) and transmitting the sensor data to the server (300) over the wireless network communication.
17. A method for determining a current operating condition and switching communication modules (204) of the data logging device (200) as claimed in claim 15, the method comprising the steps of:
 - determining, by the device management module (209), the power status of the data logging device (200);
 - computing, by the device management module (209), the travel speed of the data logging device (200) based on location data at an interval of time;
 - comparing, by the device management module (209), the travel speed with the predetermined travel speed;
 - switching, by the device management module (209), the data logging device (200) between the plurality of communication modules (204) based on the power status and/or the travel speed of the data logging device (200),wherein the device management module (209) switches the data logging device (200) between the high power communication module for high frequency transmission of

the sensor data and high power consumption when the data logging device (200) is receiving power from the power source and/or the travel speed is higher than the predetermined travel speed, and the low power communication module for low frequency transmission of the sensor data and low power consumption when the data logging device (200) is not receiving power from the power source and/or the travel speed is lower than the predetermined travel speed.