

AGRICULTURAL WORKER MANAGEMENT SYSTEM AND METHOD

TECHNICAL FIELD OF INVENTION

[001] The following relates to an agricultural worker management system and a method for agricultural worker management.

BACKGROUND

[002] Agriculture generally involves a wide range of resources, including workers that need to be deployed in a methodical and efficient manner. Agricultural processes need to be scaled up for very large land areas, making management of the resources challenging.

[003] Current agricultural management systems focus on managing individual operational aspects in isolation and are often manual. Additionally, management of workers is challenging given the large number of workers and tasks that they are required to perform and uncertainty whether such tasks have been successfully performed.

[004] Known worker management systems usually involve manual reporting processes with large amounts of paperwork to document activities and tasks. Scheduling of activities and tasks may be carried out using a computer system aided by reports generated by the same system. However, tasking of workers and recording the result of such tasks are still manual.

[005] Furthermore, known systems require expert human input to determine the subsequent set of tasks given the results of prior tasks and activities. Additional information such as weather, availability of workers, availability of other resources such as tractors, refineries and delivery trucks may also need to be factored in. Once such tasks and activities have been defined, these then need to be communicated manually to the workers. Given the large amount of manual and human interaction required, existing systems are prone to inefficiencies and errors. Furthermore, known systems have no way of accurately tracking the actual location and activities of workers.

[006] A need therefore exists to provide agricultural worker management systems and methods that seek to address at least some of the above-mentioned problems.

SUMMARY

[007] According to a first aspect of the invention, there is provided an agricultural worker management system, comprising: a worker tracker comprising a data acquisition unit (DAU)

having location information associated with a worker, and an inertial measurement unit (IMU) configured to determine movements of the worker; one or more memory modules having stored thereon at least one pre-defined worker management rule, wherein the one or more memory modules further have stored thereon a plurality of tasks for the worker, and a processor in communication with the one or more memory modules and the worker tracker to receive the location information associated with the worker and movement information of the worker, wherein the processor is configured to select a task for the worker based on the location information associated with the worker and at least one worker management rule, wherein the worker tracker is configured to provide information indicative of a completion of the selected task by the worker, and wherein the processor is further configured to evaluate a performance of a completed task by the worker based on the location and movement information of the worker relative to a location of the selected task to dynamically select a subsequent task for the worker based on the evaluated performance. The location information associated with the worker comprises a detected geographical location of the worker and/or a known location of the worker.

[008] In an embodiment, the system may further comprise a location tracker in communication with the DAU and configured to detect the geographical location of the worker, and wherein the DAU is configured to acquire the detected geographical location from the location tracker.

[009] In an embodiment, the system may further comprise a user input module in communication with the DAU and configured to receive the known location of the worker, and wherein the DAU is configured to acquire the known location of the worker from the user input module.

[010] In an embodiment, the one or more memory modules may have further stored thereon a plurality of rewards for the worker, and wherein the processor is further configured to assign a reward for the completion of the selected task based on the location information associated with the worker and the at least one worker management rule.

[011] In an embodiment, the worker tracker may comprise an *activity tracker* configured to provide the information indicative of the completion of the selected task by the worker wherein the processor is in communication with the activity tracker to receive the information indicative of the completion. The activity tracker may comprise a load sensor to determine an amount of an agricultural product being handled by the worker.

[0012] In an embodiment, the location tracker may comprise a satellite-based positioning system receiver that may be attached to the worker.

[0013] In an embodiment, the location tracker may comprise a radio-frequency identification (RFID) sensor or motion sensor.

[0014] In an embodiment, the processor may be further configured to store the movement information of the worker in the one or more memory modules. The IMU may comprise one or more of a gyroscope, accelerometer, and magnetometers.

[0015] In an embodiment, the processor may be further configured to receive mapping data and select the task for the worker based on the mapping data.

[0016] In an embodiment, the processor may be further configured to receive weather data that is associated with the location information associated with the worker and select the task for the worker based on the weather data.

[0017] In an embodiment, the processor may be further configured to receive data from an Enterprise Resource Planning (ERP) system and select the task for the worker based on the data from the ERP system.

[0018] In an embodiment, the system may further comprise a display unit in communication with the processor, the display unit configured to display the selected task for the worker.

[0019] In an embodiment, each task may be associated with a time to commence the task, a time to complete the task, and/or a location to perform the task.

[0020] According to a second aspect of the invention, there is provided a method of agricultural worker management, comprising: obtaining location information associated with a worker using a worker tracker comprising a data acquisition unit (DAU); determining movements of the worker using the worker tracker that further comprises an inertial measurement unit (IMU); storing at least one pre-defined worker management rule and a plurality of tasks for the worker on one or more memory modules; selecting a task for the worker based on the location information associated with the worker and the at least one worker management rule using a processor in communication with the one or more memory modules and the worker tracker; providing information indicative of a completion of the selected task by the worker using the worker tracker; evaluating a performance of a completed task by the worker based on the location and movement information of the worker relative to a location of the selected task using the processor; and dynamically selecting, by the processor, a subsequent task for the worker based on the evaluated performance. The location information associated with the worker comprises a detected geographical location of the worker and/or a known location of the worker.

[0021] In an embodiment, the method may further comprise detecting the geographical location of the worker using a location tracker in communication with the DAU.

[0022] In an embodiment, the method may further comprise receiving the known location of the worker using a user input module in communication with the DAU.

[0023] In an embodiment, the method may further comprise: storing a plurality of rewards for the worker on the one or more memory modules, and assigning, using the processor, a reward for the completion of the selected task

based on the location information associated with the worker and the at least one worker management rule.

[024] In an embodiment, the method may further comprise: evaluating performance of the selected task by the worker using an activity tracker in communication with the processor; and selecting a subsequent task for the worker based on the evaluated performance using the processor.

BRIEF DESCRIPTION OF THE DRAWINGS

[025] Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

[026] Figure 1a is a schematic showing the components of an agricultural worker management system according to an embodiment of the invention;

[027] Figure 1b is a schematic showing the components of an agricultural worker management system according to another embodiment of the invention;

[028] Figure 2 is a schematic showing the components of a worker tracker according to an embodiment of the invention;

[029] Figure 3 is a schematic showing a piece of agricultural land that requires harvesting;

[030] Figure 4 is a schematic showing the components of an exemplary wireless device which may be used to realize a worker tracker according to an embodiment of the invention;

[031] Figure 5 is a schematic showing the components of an exemplary computing device which may be used to realize a processing system according to an embodiment of the invention; and

[032] Figure 6 is a flowchart illustrating a method of agricultural worker management according to an embodiment of the invention.

DETAILED DESCRIPTION

[033] Embodiments of the present invention will be described, by way of example only, with reference to the drawings. Like reference numerals and characters in the drawings refer to like elements or equivalents.

[034] Some portions of the description which follows are explicitly or implicitly presented in terms of algorithms and functional or symbolic representations of operations on data within a computer memory. These algorithmic descriptions and functional or symbolic representations are the means used by those skilled in the data processing arts to convey most effectively the substance of their work to others

skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities, such as electrical, magnetic or optical signals capable of being stored, transferred, combined, compared, and otherwise manipulated.

[035] Unless specifically stated otherwise, and as apparent from the following, it will be appreciated that throughout the present specification, discussions utilizing terms such as "selecting", "scanning", "calculating", "determining", "replacing", "generating", "initializing", "outputting", or the like, refer to the action and processes of a computer system, or similar electronic device, that manipulates and transforms data represented as physical quantities within the computer system into other data similarly represented as physical quantities within the computer system or other information storage, transmission or display devices.

[036] The present specification also discloses apparatus for performing the operations of the methods disclosed herein. Such apparatus may be specially constructed for the required purposes, or may comprise a general purpose computer or other device selectively activated or reconfigured by a computer program stored in the computer. The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose machines may be used with programs in accordance with the teachings herein. Alternatively, the construction of more specialized apparatus to perform the required method steps may be appropriate. The structure of a conventional general purpose computer will appear from the description below.

[037] In addition, the present specification also implicitly discloses a computer program, in that it would be apparent to the person skilled in the art that the individual steps of the method described herein may be put into effect by computer code. The computer program is not intended to be limited to any particular programming language and implementation thereof. It will be appreciated that a variety of programming languages and coding thereof may be used to implement the teachings of the disclosure contained herein. Moreover, the computer program is not intended to be limited to any particular control flow. There are many other variants of the computer program, which can use different control flows without departing from the spirit or scope of the invention.

[038] Furthermore, one or more of the steps of the computer program may be performed in parallel rather than sequentially. Such a computer program may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other

storage devices suitable for interfacing with a general purpose computer. The computer readable medium may also include a hard-wired medium such as exemplified in the Internet system, or wireless medium such as exemplified in the GSM, GPRS, 3G or 4G mobile telephone systems as well as other wireless systems such as Bluetooth, ZigBee, Wi-Fi. The computer program when loaded and executed on such a general-purpose computer effectively results in an apparatus that implements the steps of the preferred method.

[039] The invention may also be implemented as hardware modules. More particular, in the hardware sense, a module is a functional hardware unit designed for use with other components or modules. For example, a module may be implemented using discrete electronic components, or it can form a portion of an entire electronic circuit such as an Application Specific Integrated Circuit (ASIC) or Field Programmable Gate Array (FPGA). Numerous other possibilities exist. Those skilled in the art will appreciate that the system can also be implemented as a combination of hardware and software modules.

[040] Embodiments of the invention seek to provide systems and methods for agricultural worker management; and for incentivization of agricultural worker tasks, commands and instructions. For the sake of conciseness, the terms "tasks", "commands" and "instructions" will be collectively referred to as "tasks" in the following description.

[041] Figure 1a is a schematic showing the components of an agricultural worker management system 100 according to an embodiment of the invention. The system 100 comprises a data acquisition unit (DAU) 101 having location information associated with a worker, one or more memory modules (for simplicity, only one memory module 110 is shown) having stored thereon at least one pre-defined worker management rule and a plurality of tasks for the worker, and a processor 114 in communication with the one or more memory modules (e.g. memory module 110) and the DAU 101 to receive the location information associated with the worker. The processor 114 is configured to select a task for the worker based on the location information associated with the worker and the at least one worker management rule. The one or more memory modules may be located at different locations or in close proximity (e.g. in a server room). Further, each memory module may only store the pre-defined worker management rule(s); or only store the plurality of tasks for the worker; or both the pre-defined worker management rule(s) and the plurality of tasks for the worker.

[042] The location information associated with the worker may include a detected geographical location of the worker and/or a known location of the worker.

[043] The system 100 may further comprise a location tracker 102a in communication with the DAU 101 and configured to detect the geographical location of the worker, and the DAU 101 is configured to acquire the detected geographical location from the location tracker 102a. In this context, a detected geographical location may be latitude / longitude coordinates, satellite navigation system (e.g. Global Positioning System (GPS)) coordinates or any other information capable of locating the worker at a certain location in the world.

[044] Alternatively or in addition, the system 100 may further comprise a user input module 122a in communication with the DAU 101 and configured to receive the known location of the worker, and the DAU 101 is configured to acquire the known location of the worker from the user input module 122a. The user input module 122a, in a basic form, may be a device with an input device (e.g. keyboard, keypad, etc.) and optionally a display screen for displaying a graphical user interface or the data that is inputted. A user inputs a known location of the worker into the user input module 122a. In this context, a known location of the worker may be a specific location or general vicinity, but is known to the user (i.e. not detected by a location tracker). For example, a plantation may be divided into a number of zones, and plantation workers are pre-assigned a zone to work at by the user. The user can then input this information (e.g. Worker "X" is assigned to Zone "Y") so that it is assumed that the known location of Worker "X" is at Zone "Y".

[045] The DAU 101, in a basic form, is configured to acquire the detected geographical location of the worker from the location tracker 102a and/or a known location of the worker from the user input module 122a. In an implementation, the DAU 101 may continuously poll the location tracker 102a or user input module 122a for the location of the worker and send this information to the processor 114. In another implementation, the DAU 101 may simply be a passive conduit used for relaying the location of the worker from the location tracker 102a or user input module 122a to the processor 114. If necessary, the DAU 101 may be configured to convert the data received from the location tracker 102a or user input module 122a to a format recognized by the processor 114.

[046] Figure 1b is a schematic showing the components of another agricultural worker management system 150 according to another embodiment of the invention.

[047] The system 150 comprises one or more worker trackers 102 (for illustration, three worker trackers are shown in Figure 1b). The worker trackers 102 are configured to determine the geographical location of workers and may also capture various inputs or activities relating to the workers such as, but not limited to,

amount of fertilizer / pesticide dispensed or amount of produce (crops, fruit, etc.) harvested. The captured data (e.g. geographical location, input and/or activity) can be stored and/or communicated to other devices of the agricultural worker management system 150.

[048] In an example implementation, worker trackers 102 may take a form of a device that is worn by each worker in the field. The device is capable of determining the geographical location of the worker, receiving information from other sensors / devices to determine information such as the amount of fertilizer / pesticide dispensed, and/or receiving tasks and display such tasks. The worker trackers 102 may be functionally similar to the location tracker 102a.

[049] In another implementation, the worker trackers 102 may comprise fixed sensors installed at known locations in the plantation to track the location of workers. Such sensors may include long range radio-frequency identification (RFID) sensors and motion sensors. For example, a worker wears a RFID tag and a RFID sensor (placed at a known location) is triggered when the worker is in the vicinity of the RFID sensor. The plantation manager can be notified of the triggering of the sensor. In this manner, the geographical location of the worker can be tracked.

[050] In yet another implementation, passive radio frequency sensors may be used to monitor emanations from mobile phones or other transmitters that workers may carry with them. Using signal triangulation in combination with unique IDs associated with such mobile phones (e.g. IMEI number), it is possible to uniquely track each worker's location.

[051] In some cases, it may not be necessary to track the identity of a worker as accurately as the location of the worker. In such cases, motion sensors such as passive infrared (PIR) motion sensors, seismic sensors and other similar sensors can be used to identify the presence of the worker.

[052] In an implementation, a worker tracker 102 may comprise the following modules: (i) a location tracker configured to determine the geographical location of a worker; and (ii) an activity tracker configured to evaluate the performance of a task performed by a worker.

[053] The location tracker may comprise a Global Positioning System (GPS) receiver for tracking the location of the worker when the device is worn by the worker. The location tracker may also use other types of positioning technologies such as different types of satellite-based navigation systems (e.g. GLONASS, Beidou and Galileo) or ground-based positioning systems that may be based on technologies such as radio frequency technologies (e.g. LORAN and Omega) or be a combination of several such technologies and may also utilize an inertial navigation

unit for further accuracy. Some of these systems may also be used in conjunction with unmanned aerial vehicles (drones) that are equipped with motion sensing equipment which may be optical or radar based and may optionally have other radio transceivers for communication. The drones may be piloted and flown within the vicinity of the plantation. The drones may function as a relay / communications link between the worker tracker 102 and processing system 114.

[054] The activity tracker may comprise a load sensor or strain gauge to determine an amount of an agricultural product being handled by the worker. For example, if the agricultural product is fertilizer, the load sensor can determine an amount of fertilizer being handled by the worker. The load sensor may be physically attached to a receptacle (at a suitable location, e.g. the base of the container) used to contain the agricultural product. The worker may carry the receptacle or tow the receptacle along with him. Alternatively, the receptacle may be placed on a self-propelled vehicle (e.g. a tractor) and accompanies the worker as he dispenses the fertilizer. As the worker dispenses the fertilizer, the load handled by the worker decreases and the change in load is detected by the load sensor. If the agricultural product is a fruit being harvested, the load sensor can determine an amount of fruit harvested and handled by the worker. As the worker harvests the fruit, the load handled by the worker increases and the change in load is detected by the load sensor. *The changes in load can provide an indication of the performance of tasks by workers; greater loads handled during a harvesting related task may imply that a worker is performing better.* The processing system 114 may be configured to select a subsequent task for the worker based on his evaluated performance (i.e. his performance of a previously assigned task). For example, a worker's initial task is to dispense fertilizer at a certain location. Based on the load sensor's reading, it can be determined that insufficient fertilizer was dispensed at that location. As such, a possible subsequent task assigned to the worker may be to re-visit the location and dispense more fertilizer.

[055] If the worker's activity is tracked together with his location, the worker tracker can advantageously determine the activity being performed at the location. In this manner, it is difficult for the worker to simply dispense fertilizer at any random location and claim that he has completed his job. If the location of crops is known, it is expected that there is a change in load detected by the load sensor at locations where crops are present. If crops are not present and the load sensor detects a change in load, the worker may be simply dumping fertilizer at any convenient location and claim that he has completed his job. Furthermore, workers may need to perform the dispensing in a specific manner / pattern that the worker tracker, through

the various sensors (e.g. gyroscope, compass and accelerometer), can detect and monitor. In another application, if the plantation manager tasks a worker to dispense fertilizer at a particular location, the worker tracker is able to determine that the worker dispenses fertilizer at the particular location, not at some other location.

[056] Figure 2 is a schematic showing the components of a worker tracker 200 according to an embodiment of the invention. The worker tracker 200 comprises a microcontroller 252 which is in communication with at least one of a number of modules including, but not limited to: a worker identification system 254, a Global Positioning System (GPS) receiver 256, an accelerometer 258, a gyroscope 260, a barometric pressure sensor 262, a digital compass / magnetometer 264 and an activity tracker 266 (shown in the form of a "fertilizer use sensor" in Figure 2).

[057] The accelerometer 258, gyroscope 260, barometric pressure sensor 262, and digital compass / magnetometer 264 can be used to determine an orientation / movements of the worker. While the GPS receiver 256 can determine the geographical location of the worker, the GPS receiver 256 may not be able to detect minute movements to the worker. For example, if the worker is dispensing fertilizer around a palm oil tree, the GPS receiver may detect that he is stationary, or provide signals that could be interpreted as noise, but in reality the worker is walking around the tree. The accelerometer 258, gyroscope 260 and/or digital compass / magnetometer 264 can detect his orientation / movements around the tree.

[058] In the following description, the accelerometer 258, gyroscope 260 and digital compass / magnetometer 264 are collectively referred to as inertial measurement devices, which may be integrated into a single inertial measurement unit (IMU). In some implementations, the barometric pressure sensor 262 may be integrated with the IMU to form a single supplementary sensor unit. In some plantations where the vegetation may be thick, the GPS receiver may experience weak GPS signal reception and consequently geographical location tracking may be inaccurate or lagging. The inertial measurement devices and/or barometric pressure sensor 262 may be used to supplement the GPS receiver's geographical location tracking of the worker using sensor fusion techniques such as a Kalman filter.

[059] In an example implementation, the activity tracker 266 may include a strain gauge or load sensor embedded in a receptacle that is handled by the worker. The worker may carry the receptacle or tow the receptacle along with him. Alternatively, the receptacle may be placed on a self-propelled vehicle (e.g. a tractor) and accompanies the worker as he dispenses the fertilizer / pesticide or harvests crops / fruit. When fertilizer / pesticide is dispensed, the load sensor detects the weight of the fertilizer / pesticide removed from the receptacle to determine the

amount of fertilizer / pesticide that is used. When crops / fruit is harvested and collected, the load sensor detects the weight of the crops / fruit added to the receptacle to determine the amount of crops / fruit that is collected.

[060] Turning back to the worker tracker 200, the information received from the plurality of modules (i.e. worker identification system 254, GPS receiver 256, accelerometer 258, gyroscope 260, barometric pressure sensor 262, digital compass / magnetometer 264 and activity tracker 266) is processed by the microcontroller 252 and stored on a data storage device 268. The microcontroller 252 may also receive inputs via a data entry system 278 and the microcontroller 252 may also send raw or processed data from the modules or inputs from the data entry system 278 over a wireless link 203, or a docking station link 205, to a processing system 114 of the agricultural worker management system 150. The docking station link 205 works by transmitting signals over communication protocols when the worker tracker 200 is docked into or placed adjacent a docking station (not shown in Figure 2). For example, communication protocols such as GSM, UMTS, Wi-Fi, Bluetooth or Near-field communication (NFC) can be used to receive data from the worker tracker 200. Alternatively or in addition, the worker tracker 200 may have a Universal Serial Bus (USB) port which can be plugged into a docking station with a complementary USB connector. Other wired communication techniques may also be utilized, including a serial port, parallel port, SPI interface and 1-Wire interface. A drone platform or similar airborne platform with radio frequency links may also be utilized to communicate with worker trackers 200.

[061] The microcontroller 252 may also be capable of receiving alerts, tasks or other information over the wireless link 203 or docking station link 205. The alerts, tasks or other information may be displayed on a visual display system / unit 274 or via an audio notification system 276.

[062] Referring back to Figure 1b, the system 150 further comprises a processor / processing system 114. The worker tracker 102 may communicate with the processing system 114 over a wireless link 103 or via a docking station link 105 where data can be downloaded from / uploaded to the worker tracker 102 at the end of a work cycle. The processing system 114 may retrieve such data from worker tracker 102 and store the data in a data storage system or memory module 110. This communication may be periodic (such as at the end of a shift) or in real-time depending on the implementation.

[063] The system 150 may be communicatively coupled to a plantation Enterprise Resource Planning (ERP) system 104, mapping data source 106, and weather data source 108. In an implementation, the ERP system 104, mapping data

source 106, and weather data source 108 are external modules that are not part of the system 150. The processing system 114 may query and receive a plurality of inputs from the ERP system 104, mapping data source 106, and weather data source 108, which can be combined with an expert system 116 and various rules, constraints, logic or requirements 118 that may be defined from time to time or even obtained from other sources such as the ERP system 104. For the sake of brevity, the terms "rules", "constraints", "logic" and "requirements" are collectively referred to as "worker management rules" or simply "rules" in the following description. An example of a rule is "The oil palm trees must be watered every Tuesday". Another rule might be "If there was heavy rain recorded yesterday, reschedule harvesting to another field". Yet another rule might be "Ensure that harvesters visit each crop field at least once every two weeks at a minimum". A plurality of rules may be defined and stored in the data storage system or memory module 110.

[064] In an implementation, the expert system 116 may be configured as a rule-based decision system with artificial intelligence in order to emulate the decision-making ability of a human expert. The expert system 116 may be designed to solve complex problems by reasoning about knowledge, represented primarily as "if-else" rules rather than through conventional procedural code. A basic form may include a rule engine coupled with a knowledge base of scenarios. The expert system 116 may contain logic so that, e.g. if heavy rain was recorded on the previous day at a certain area, the worker is automatically instructed to harvest another area.

[065] The expert system 116 may also be capable of machine learning. In an implementation, a model may be built based on suitable inputs so that the expert system 116 can be trained to make predictions and/or decisions, rather than following the "if-else" rules mentioned above. Various machine learning approaches may be used to implement the expert system 116 and a combination of approaches may also be used. Methods such as decision tree learning, neural networks and genetic algorithms are just some of the approaches that can be used. In an example implementation, the expert system 116 can be used to automatically attempt various worker scheduling schemes to maximize the plantation area visited. First, a population of scheduling schemes are generated or seeded. A selected number of schemes can then be chosen based on a fitness function, which in this case may be used to evaluate the scheduling schemes for the plantation area visited. The expert system 116 may incorporate a model of worker behaviour based on previously recorded worker activity and location data or other models developed to simulate the system in question and assist in the evaluation of the fitness function. Subsequently, the next generation of the population is generated from these selected schemes

through use of genetic operations (e.g. crossover and mutation). This process of selection and genetic mutation repeats until various termination criteria are met, for example when the fitness function score reaches a certain threshold.

[066] A plurality of tasks may be defined and stored in the data storage system or memory module 110. An example of a task that is related to the rule "The oil palm trees must be watered every Tuesday" is "Water every oil palm tree in Sector A every Tuesday starting at 9 AM and finishing at 1 PM". Each task may be associated with a time to commence the task (e.g. every Tuesday, 9 AM), a time to complete the task (e.g. 1 PM), and/or a location (e.g. Sector A) to perform the task. An example task related to the rule "Ensure that harvesters visit each crop field at least once every two weeks at a minimum" is "Schedule Sector A to be harvested tomorrow before 12 noon".

[067] The processing system 114 is configured to process / analyse information obtained from the worker trackers 102. Based on the various rules (that may be set, chosen and input by plantation managers) and information from the worker trackers 102 (geographical location and/or performance of task), the processing system 114 is able to select one or more tasks for the worker to perform in order to achieve a predetermined goal or target (e.g. a good harvest, which requires consistent watering of crops). Continuing from the example above, only workers at / near Sector A are assigned the task of "Water every oil palm tree in Sector A every Tuesday starting at 9 AM and finishing at 1 PM". Workers at sectors far away from Sector A are not assigned the task. In another example, if urgent dispensing of fertilizer is required in Sector B, only workers with sufficient fertilizer (the amount of fertilizer being detected using the activity tracker 266 of the worker tracker 102) may be assigned the task of fertilizing the crops in Sector B. The processing system 114 may also be configured to automatically schedule tasks and/or modify existing tasks.

[068] In an implementation, the data storage system 110 may store a plurality of tasks and/or rules (and their associated parameters and priority scores). Based on input (e.g. the location of the worker) and the rules, the processing system 114 selects a task for the worker to perform.

[069] Tasks and rules may have priorities (embodied by e.g. priority score) and other parameters associated with them to allow for automatic task prioritization in the event of limited time or resources. For example, a rule of "Ensure each field is harvested at least every two weeks" can be made more important than a rule "Ensure each field is inspected for harvesting a day after each harvest" such that if only a limited number of workers are available, other fields are harvested first before

considering assigning workers to inspect the fields. Thus, the processing system 114 may determine or allow certain rules or tasks to be broken or rescheduled according to a priority score and also taking into account other factors such as the number of unoccupied workers and location of these workers. The processing system 114 may automatically evaluate various combination of tasks, taking into account the priority score as well as resources and time available, in order to maximize the number of tasks and rules executed or followed. Furthermore, the processing system 114 may modify tasks such that the task may take shorter to complete in order to free up resources for higher priority tasks. The system may run numerous such simulations using methods such as Monte Carlo to randomly attempt various combinations of tasks and rules and their associated parameters in order to determine the most optimal configuration. Other techniques can be used in conjunction or in substitution of the Monte Carlo method. Such techniques can include heuristics, genetic algorithms, hill climbing methods, gradient descent/ascent and iterative methods. These can further be combined with probability models in relation to the outcomes or likely outcomes of the tasks or rules as well as Bayesian statistics to further improve the *decision making capability of the system*.

[070] In an implementation, the processing system 114 is further configured to receive / processes data from other sources such as weather data source 108, mapping data source 106 (maps, satellite images, aerial images, airborne drones etc. that may capture visible spectrum, IR or UV data which may be further processed or combined with other data sources to generate other useful data such as moisture content) and ERP system 104. Based on the (i) various rules, (ii) information from the worker trackers 102 (geographical location and/or performance of task) and (iii) data from these sources, the processing system 114 is able to select one or more tasks for the worker to perform. Continuing from the example above, if weather data from weather data source 108 indicates that dry weather is forecasted at Sector A, workers at / near Sector A are assigned the task of "Water every oil palm tree in Sector A *everyday* starting at 9 AM and finishing at 1 PM".

[071] As a further example, if a certain areas in Sector A are known be more susceptible to soil erosion (e.g. from mapping data, the area lies on a steep slope), the selected task may be "Water every oil palm tree in Sector A *everyday* starting at 9 AM and finish at 1 PM *and check for signs of soil erosion*".

[072] Embodiments of the invention seek to improve one or more aspects of agricultural operation (e.g. crop yield, worker productivity, etc.) by selecting and assigning tasks to agricultural workers based on one or more of: (i) geographical location of workers (determined by worker trackers), (ii) pre-defined worker

management rules, (iii) performance of tasks by workers (determined by worker trackers), and (iv) other sources of data, e.g. weather data source 108, mapping data source 106 and ERP system 104.

[073] The processing system 114 may additionally handle other tasks such as recording of (i) worker attendance, (ii) geographical location of workers and/or (iii) any other events or activities, using the remote location, sensing and communication ability of embodiments of the present invention. For example, plantation managers can track the movements of workers so that workers who move around more (presumably working harder) may be better rewarded compared to workers who move around less. Display system 120 and user interface 122 may be used by plantation managers to pre-define the various rules and tasks, and to monitor the location and activities of the workers out in the field.

[074] The processing system 114 may operate substantially in real-time such that workers in the field can dynamically receive updated tasks in response to changes such as a lack of workers turning up for a shift or an urgent requirement to harvest a particular area.

[075] The agricultural worker management system of the example embodiments may be further configured to provide for incentivization of agricultural worker tasks with the aim of motivating agricultural workers and incentivizing agricultural work. For example, points may be assigned for performing / completing certain agricultural worker tasks or achieving certain results. These points could then be tied to a real-life reward (e.g. increased remuneration).

[076] The processing system 114 is further configured to provide for incentivization of agricultural worker tasks. The processing system 114 may be configured to assign a reward for the worker upon completion of a selected task that is assigned to the worker. The assignment is based on one of more of: (i) incentivization rules, (ii) the geographical location of the worker, (iii) performance of tasks by workers, (iv) pre-defined worker management rules 118, and (v) data from weather data source 108, mapping data source 106 and ERP system 104.

[077] The incentivization rules can take various forms, one example may be "If the morning's harvest coverage was below 80%, double the points awarded for the afternoon's harvest shift" and another may be "Offer workers triple points for harvesting distant fields over 10km from the main road", whereby a rule may contain a reward multiple (e.g. double points) that is variable. These rules can be configured to provide the appropriate incentives to ensure various tasks and rules are met and can be combined together with the capability of the processing system to create and modify tasks and rules described above. In an embodiment of this system, the

system may dynamically modify and monitor the response of the reward multiple to ensure that only enough incentivization is provided. In the example above, if offering triple points was too successful, the system may modify the reward so that in future only double points are given. The system may also track price elasticity through such experiments and combine this with probability models to help determine appropriate incentive multiple levels as well as estimate the likelihood of task success.

[078] A plurality of rewards may be defined and stored in the data storage system or memory module 110. The processing system 114 is configured to choose one or more rewards from the plurality of rewards and assign the chosen reward to a particular task.

[079] In an implementation, the processing system 114 is configured to use one of more of: (i) the geographical location of the worker, (ii) performance of tasks by workers, (iii) pre-defined worker management rules 118, (iv) data from weather data source 108, mapping data source 106 and ERP system 104 to automatically, or with expert input, compute performance measurements of each worker, prescribe incentives and rewards for workers, and schedule / alter tasks with the goal of improving any specified performance measurement.

[080] By examining data relating to actual worker activity (e.g. geographical location and/or performance of task) in combination with rules 118, incentivization rules and various expert systems 116, the processing system 114 is able to determine worker performance metrics and automatically determine or modify rewards and tasks for the workers to perform to achieve a predetermined goal or target set by the plantation manager.

[081] The performance metrics, rewards and tasks may then be communicated to the workers (e.g. via a user interface displayed on a screen of the worker tracker 102) or plantation management (e.g. via display systems 120 and user interface 122). The performance measurements may be linked to real-life rewards (e.g. monetary rewards) which may be communicated to the workers. A plantation manager may use the user interface 122 to access, modify and operate the system 150.

[082] In an implementation, the processing system 114 is configured to assign a reward for the worker upon accomplishment of a particular performance metric. For example, if the performance metric is "Harvesting of 50 kg of fruit in one month", the worker may be rewarded at the end of the month if he is able to accomplish the performance metric of harvesting 50 kg of fruit in that month.

[083] The processing system 114 may operate substantially in real-time such that workers in the field can receive dynamically altering rewards or tasks in response to changes such as an urgent requirement to harvest a particular area.

[084] Figure 3 is a schematic showing a piece of agricultural land that requires harvesting. With reference to Figures 1 and 3, the piece of land that requires harvesting is denoted as 31. This requirement is input by the plantation manager via the user interface 122 into the system 150 which may store the requirement in the data storage system 110. The manager may also determine he wishes to have 100% harvesting coverage so that the entire piece of land 31 is visited by a worker at least once. The corresponding rule may be "100% harvesting coverage of Sector 31". The corresponding task may be "Harvest every oil palm tree in Sector 31".

[085] The processing system 114 then dispatches the task to the workers (e.g. via worker trackers 102) based on the pre-defined rule and other data in order to determine which workers to notify and assigns a standard reward for completing the task. For example, based on the determined location of workers, only workers around Sector 31 are assigned the task. If the worker tracker indicates that the worker assigned the task visits every oil palm tree in Sector 31, the assigned reward may be given to the worker.

[086] Each task or rule may have an associated reward assigned by the plantation manager through the data entry system 278 or automatically by the processing system 114 in order to incentivize the workers to perform and complete the task. In an embodiment, the processing system 114 may in a first instance assign a default reward to tasks or rules that do not have an assigned reward. The default reward level may be a fixed level that is the same across all tasks or rules or can be calculated based on the priority score and estimated time taken for each task such that the time value of labour as well as task importance is taken into account. Based on the response and success of the task, the processing system may modify the reward to achieve an optimal state whereby such parameters of an optimal state may be set by the estate manager.

[087] After harvesting, the data regarding the areas visited by the workers is communicated to the processing system 114 from the worker trackers 102. After processing the data, the processing system 114 determines which areas were visited and whether there are any unvisited areas. For example, in Figure 3, area 32 (shaded) was visited / harvested however there is an area 33 that was not visited / harvested. Using incentivization rules (e.g. increased reward to unvisited areas) input to the processing system 114, the processing system 114 offers double the standard reward for workers to visit the area 33 and notifies the workers via the worker

trackers 102, communicating both the new reward as well as the exact location of the area 33. In this manner, workers are incentivized to visit area 33 and thus successfully achieving the managers' performance metric of 100% harvesting coverage. In the event that workers are not sufficiently incentivized to visit the area 33 (e.g. the terrain of area 33 is very challenging making it relatively inaccessible), or on a second pass the area 33 is not completely covered, then the processing system 114 may then further increase the reward until workers are incentivized to harvest the area. The processing system 114 may be capable of learning the response to different rewards to calculate the price elasticity, allowing the processing system 114 to choose the appropriate reward level more accurately on the first pass, potentially reducing the need for future visits so as to further free up resources that may otherwise have been consumed for repeated visits.

[088] An exemplary wireless device 400 which may be used to realize (at least part of) the worker tracker 102 is described below with reference to Figure 4.

[089] The wireless device 400 comprises a keypad 402, a touch-screen 404, a microphone 406, a speaker 408 and an antenna 410. The wireless device 400 is capable of being operated by a user to perform a variety of different functions, such as, for example, hosting a telephone call, sending an SMS message, browsing the Internet, sending an email and providing satellite navigation.

[090] The wireless device 400 comprises hardware to perform communication functions (e.g. telephony, data communication), together with an application processor and corresponding support hardware to enable the wireless device 400 to have other functions, such as, messaging, Internet browsing, email functions and the like. The communication hardware is represented by the RF processor 412 which provides an RF signal to the antenna 410 for the transmission of data signals, and the receipt thereof. Additionally provided is a baseband processor 414, which provides signals to and receives signals from the RF Processor 412. The baseband processor 414 also interacts with a subscriber identity module 416, as is well known in the art. The communication subsystem enables the wireless device 400 to communicate via a number of different communication protocols including 3G, 4G, GSM, WiFi, Wi-fi direct, Bluetooth™ and/or CDMA. The communication subsystem of the wireless device 400 is beyond the scope of the invention.

[091] The keypad 402 and the touch-screen 404 are controlled by an application processor 418. A power and audio controller 420 is provided to supply power from a battery 422 to the communication subsystem, the application processor 418, and the other hardware. The power and audio controller 420 also controls input

from the microphone 406, and audio output via the speaker 408. Also provided is a global positioning system (GPS) antenna and associated receiver element 424 which is controlled by the application processor 418 and is capable of receiving a GPS signal for use with a satellite navigation functionality of the wireless device 400.

[092] In order for the application processor 418 to operate, various different types of memory are provided. Firstly, the wireless device 400 includes Random Access Memory (RAM) 426 connected to the application processor 418 into which data and program code can be written and read from at will. Code placed anywhere in RAM 426 can be executed by the application processor 418 from the RAM 426. RAM 426 represents a volatile memory of the wireless device 400.

[093] Secondly, the wireless device 400 is provided with a long-term storage 428 connected to the application processor 418. The long-term storage 428 comprises three partitions, an operating system (OS) partition 430, a system partition 432 and a user partition 434. The long-term storage 428 represents a non-volatile memory of the wireless device 400.

[094] The touch-screen 404 is capable of displaying user interfaces that allow workers to interact with plantation managers and accept / manage tasks assigned to them.

[095] In the present example, the OS partition 430 contains the firmware of the wireless device 400 which includes an operating system. Other computer programs may also be stored on the long-term storage 428, such as application programs, and the like. In particular, application programs which are mandatory to the wireless device 400, such as, in the case of a smartphone, communications applications and the like are typically stored in the system partition 432. The application programs stored on the system partition 432 would typically be those which are bundled with the wireless device 400 by the device manufacturer when the wireless device 400 is first sold.

[096] Application programs which are added to the wireless device 400 by the user would usually be stored in the user partition 434.

[097] As stated, the representation of Figure 4 is schematic. In practice, the various functional components illustrated may be substituted into one and the same component. For example, the long-term storage 428 may comprise NAND flash, NOR flash, a hard disk drive or a combination of these.

[098] Although not shown, the wireless device 400 may further comprise accelerometer(s), gyroscope(s), and magnetometer(s) that function as inertial measurement devices.

[0099] An exemplary computing device which may be used to realize (at least part of) the processing system 114 is described below with reference to Figure 5.

[0100] The following description of the computing device 500 is provided by way of example only and is not intended to be limiting. Therefore, one or more elements / components of the computing device 500 may be omitted. Also, one or more elements / components of the computing device 500 may be combined together. Additionally, one or more elements / components of the computing device 500 may be split into one or more component parts.

[0101] With reference to Figure 5, the exemplary computing device 500 includes a processor 503 for executing software routines. Although a single processor is shown for the sake of clarity, the computing device 500 may also include a multi-processor system. The processor 503 is connected to a communication infrastructure 506 for communication with other components of the computing device 500. The communication infrastructure 506 may include, for example, a communications bus, cross-bar, or network.

[0102] The computing device 500 further includes a main memory 507, such as a random access memory (RAM), and a secondary memory 510. The secondary memory 510 may include, for example, a hard disk drive 512 and/or a removable storage drive 514, which may include a magnetic tape drive, an optical disk drive, or the like. The removable storage drive 514 reads from and/or writes to a removable storage unit 518 in a well-known manner. The removable storage unit 518 may include a magnetic disk, optical disk, or the like, which is read by and written to by removable storage drive 514. As will be appreciated by persons skilled in the relevant art(s), the removable storage unit 518 includes a computer readable storage medium having stored therein computer executable program code instructions and/or data. The plurality of tasks and/or rules described above may be stored in the secondary memory 510.

[0103] In an alternative implementation, the secondary memory 510 may additionally or alternatively include other similar means for allowing computer programs or other instructions to be loaded into the computing device 500. Such means can include, for example, a removable storage unit 522 and an interface 550. Examples of a removable storage unit 522 and interface 550 include a program cartridge and cartridge interface, a removable memory chip (such as an EPROM or PROM) and associated socket, and other removable storage units 522 and interfaces 550 which allow software and data to be transferred from the removable storage unit 522 to the computing device 500.

[0104] The computing device 500 also includes at least one communication interface 524. The communication interface 524 allows software and data to be transferred between computing device 500 and external devices via a communication path 526. In various implementations, the communication interface 524 permits data to be transferred between the computing device 500 and a data communication network, such as a public data or private data communication network. The communication interface 524 may be used to exchange data between different computing devices 500 which such computing devices 500 form part an interconnected computer network. Examples of a communication interface 524 can include a modem, a network interface (such as an Ethernet card), a communication port, an antenna with associated circuitry and the like. The communication interface 524 may be wired or may be wireless. Software and data transferred via the communication interface 524 are in the form of signals which can be electronic, electromagnetic, optical or other signals capable of being received by communication interface 524. These signals are provided to the communication interface via the communication path 526.

[0105] As shown in Figure 5, the computing device 500 further includes a display interface 502 which performs operations for rendering images to an associated display 530 and an audio interface 532 for performing operations for playing audio content via associated speaker(s) 534.

[0106] As used herein, the term "computer program product" may refer, in part, to removable storage unit 518, removable storage unit 522, a hard disk installed in hard disk drive 512, or a carrier wave carrying software over communication path 526 (wireless link or cable) to communication interface 524. A computer readable medium can include magnetic media, optical media, or other recordable media, or media that transmits a carrier wave or other signal. These computer program products are devices for providing software to the computing device 500. Computer readable storage medium refers to any non-transitory tangible storage medium that provides recorded instructions and/or data to the computing device 500 for execution and/or processing. Examples of such storage media include floppy disks, magnetic tape, CD-ROM, DVD, Blu-ray Disc™, a hard disk drive, a ROM or integrated circuit, USB memory, a magneto-optical disk, or a computer readable card such as a PCMCIA card and the like, whether or not such devices are internal or external of the computing device 500. Examples of transitory or non-tangible computer readable transmission media that may also participate in the provision of software, application programs, instructions and/or data to the computing device 500 include radio or infra-red transmission channels as well as a network connection to another computer or

networked device, and the Internet or Intranets including e-mail transmissions and information recorded on Websites and the like.

[0107] The computer programs (also called computer program code) are stored in main memory 507 and/or secondary memory 510. Computer programs can also be received via the communication interface 524. Such computer programs, when executed, enable the computing device 500 to perform one or more steps that facilitate the implementation of an agricultural worker management system. Accordingly, such computer programs may represent controllers of the computing device 500.

[0108] Software may be stored in a computer program product and loaded into the computing device 500 using the removable storage drive 514, the hard disk drive 512, or the interface 550. Alternatively, the computer program product may be downloaded to the computing device 500 over the communications path 526. The software, when executed by the processor 503, causes the computing device 500 to perform the necessary operations to execute one or more steps that facilitate the implementation of an agricultural worker management system.

[0109] Figure 6 is a flowchart illustrating a method of agricultural worker management according to an embodiment of the invention, comprising the following steps (in no particular order). Step 602 involves obtaining location information associated with a worker using a data acquisition unit (DAU). Step 604 involves storing at least one pre-defined worker management rule and a plurality of tasks for the worker on one or more memory modules. Step 606 involves selecting a task for the worker based on the location information associated with the worker and the at least one worker management rule using a processor in communication with the one or more memory modules and DAU. The location information associated with the worker comprises a detected geographical location of the worker and/or a known location of the worker.

[0110] The method may further comprise detecting the geographical location of the worker using a location tracker in communication with the DAU. Alternatively or in addition, the method may further comprise receiving the known location of the worker using a user input module in communication with the DAU.

[0111] The method may further comprise: (i) storing a plurality of rewards for the worker on the one or more memory modules, and (ii) assigning, using the processor, a reward for the completion of the selected task based on the location information associated with the worker and the at least one worker management rule.

[0112] The method may further comprise: (i) evaluating performance of the task by the worker using an activity tracker in communication with the processor; and

(ii) selecting the task for the worker based on the evaluated performance using the processor.

[0113] It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. An agricultural worker management system, comprising:

5 a worker tracker comprising a data acquisition unit (DAU) having location information associated with a worker, and an inertial measurement unit (IMU) configured to determine movements of the worker;

one or more memory modules having stored thereon at least one pre-defined worker management rule, wherein the one or more memory modules further have stored thereon a plurality of tasks for the worker, and

10 a processor in communication with the one or more memory modules and the worker tracker to receive the location information associated with the worker and movement information of the worker,

wherein the processor is configured to select a task for the worker based on the location information associated with the worker and at least one worker management rule,

15 wherein the worker tracker is configured to provide information indicative of a completion of the selected task by the worker, and

wherein the processor is further configured to evaluate a performance of a completed task by the worker based on the location and movement information of the worker relative to a location of the selected task to dynamically select a subsequent task for the worker based on the evaluated performance.

2. The system as claimed in claim 1, wherein the location information associated with the worker comprises a detected geographical location of the worker and/or a known location of the worker.

3. The system as claimed in claim 2, further comprising a location tracker in communication with the DAU and configured to detect the geographical location of the worker, and wherein the DAU is configured to acquire the detected geographical location from the location tracker.

4. The system as claimed in claim 2, further comprising a user input module in communication with the DAU and configured to receive the known location of the worker,

and wherein the DAU is configured to acquire the known location of the worker from the user input module.

5. The system as claimed in claim 1, wherein the one or more memory modules has
5 further stored thereon a plurality of rewards for the worker, and wherein the processor is

further configured to assign a reward for the completion of the selected task based on the location information associated with the worker and the at least one worker management rule.

- 5 6. The system as claimed in any one of the preceding claims, wherein the worker tracker comprises an activity tracker configured to provide the information indicative of the completion of the selected task by the worker wherein the processor is in communication with the activity tracker to receive the information indicative of the completion.
- 10 7. The system as claimed in claim 6, wherein the activity tracker comprises a load sensor to determine an amount of an agricultural product being handled by the worker.
- 15 8. The system as claimed in claim 7, wherein the agricultural product comprises fertilizer, pesticide or harvested produce.
- 20 9. The system as claimed in claim 3, wherein the location tracker comprises a satellite-based positioning system receiver.
- 25 10. The system as claimed in claim 9, wherein the satellite-based positioning system receiver is attached to the worker.
- 30 11. The system as claimed in claim 3, wherein the location tracker comprises a radio-frequency identification (RFID) sensor or motion sensor.
- 35 12. The system as claimed in any one of the preceding claims, wherein the processor is further configured to store the movement information of the worker in the one or more memory modules.
- 40 13. The system as claimed in claim 12, wherein the IMU comprises one or more of a gyroscope, accelerometer, and magnetometers.

14. The system as claimed in any one of the preceding claims, wherein the processor is further configured to receive mapping data and select the task for the worker based on the mapping data.

5 15. The system as claimed in any one of the preceding claims, wherein the processor is further configured to receive weather data that is associated with the location information associated with the worker and select the task for the worker based on the weather data.

10 16. The system as claimed in any one of the preceding claims, wherein the processor is further configured to receive data from an Enterprise Resource Planning (ERP) system and select the task for the worker based on the data from the ERP system.

15 17. The system as claimed in any one of the preceding claims, further comprising a display unit in communication with the processor, the display unit configured to display the selected task for the worker.

18. The system as claimed in any one of the preceding claims, wherein each task is
20 associated with a time to commence the task, a time to complete the task, and/or a location to perform the task.

19. A method of agricultural worker management, comprising:
obtaining location information associated with a worker using a worker tracker
25 comprising a data acquisition unit (DAU);
determining movements of the worker using the worker tracker that further comprises an inertial measurement unit (IMU);
storing at least one pre-defined worker management rule and a plurality of tasks for the worker on one or more memory modules;
30 selecting a task for the worker based on the location information associated with the worker and the at least one worker management rule using a processor in communication with the one or more memory modules and the worker tracker;
providing information indicative of a completion of the selected task by the worker using the worker tracker;

evaluating a performance of a completed task by the worker based on the location and movement information of the worker relative to a location of the selected task using the processor; and

5 dynamically selecting, by the processor, a subsequent task for the worker based on the evaluated performance.

20. The method as claimed in claim 19, wherein the location information associated with the worker comprises a detected geographical location of the worker and/or a known location of the worker.

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21. The method as claimed in claim 20, further comprising detecting the geographical location of the worker using a location tracker in communication with the DAU.

15 22. The method as claimed in claim 20, further comprising receiving the known location of the worker using a user input module in communication with the DAU.

23. The method as claimed in claim 19, further comprising:
storing a plurality of rewards for the worker on the one or more memory modules,

20 and

assigning, using the processor, a reward for the completion of the selected task based on the location information associated with the worker and the at least one worker management rule.