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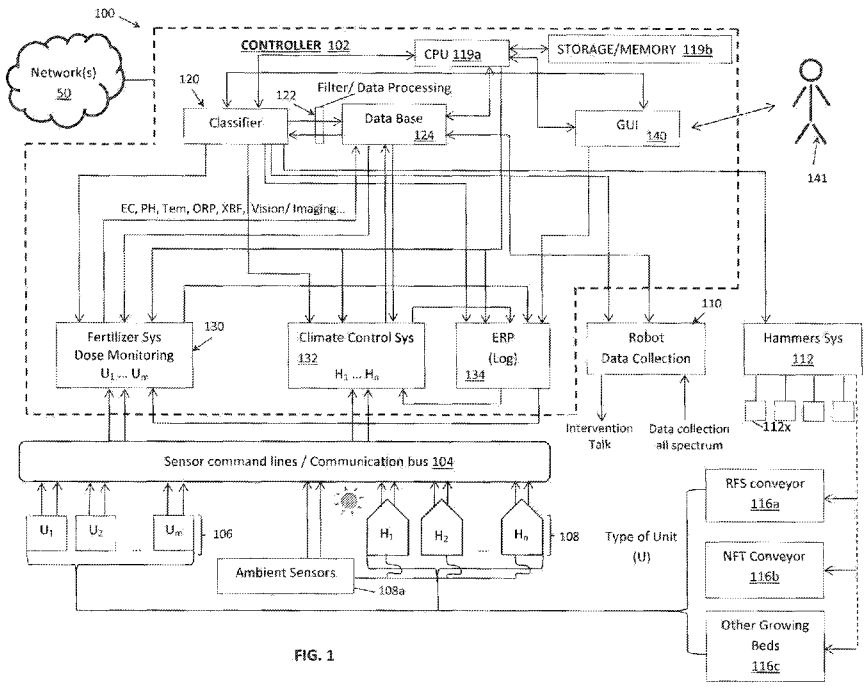


FIG. 1

(57) Abstract: The present invention is directed to computerized agricultural systems and methods for controlling and managing plant development, from seeding through harvest, in greenhouses and other agricultural production facilities.

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GREENHOUSE CONTROL SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is related to and claims priority from commonly owned US Provisional Patent Applications: Serial No. 62/657,951, entitled: Greenhouse Control System, filed on April 16, 2018, and Serial No. 62/773,210, entitled: Agricultural Robot, filed on November 30, 2018, the disclosures of which are both incorporated by reference in their entirety herein.

TECHNICAL FIELD

The present invention is directed to computerized systems for controlling plant growth and development in greenhouses and other plant growth facilities.

BACKGROUND

Most, if not all, processes in a greenhouse are performed manually. This typically requires a human manager for each greenhouse, which is inefficient, and labor intensive, and accordingly, expensive.

SUMMARY OF THE INVENTION

The present invention is directed to systems and methods for controlling and managing plant development, from seeding through harvest, in greenhouses and other agricultural production facilities. The aforementioned systems and methods are computerized, and employ artificial intelligence (AI), which is used in making various decisions associated with the management of plant development.

Also disclosed are machines for use with the system or as stand-alones. These machines include those for growing and harvesting plants on a nutrient film, as well as machines for breaking up biofilm deposits, which if left unchecked can clog irrigation pipes, as well as cause other problems in the system.

The present invention is directed to inspection, monitoring and patrol robots, such as agricultural robots, which are used to monitor plant and crop conditions in agricultural systems, and the conditions of a greenhouse, building, ground, farm, or any other space needed to be inspected, controlled and monitored. The robots are designed to perform photographic and other sensing analysis, including data analysis, of crop and plant conditions in inspected and/or monitored sites, for

example, by analyzing corresponding images of colors and their ratios associated with the crops, external condition such as the flow of water associated with the particular crop or plant section, and, disease and pest detection. The robot is designed to remember its position, location in space, as well as imaging device coordinates, at the location where the initial image was taken, including the imaging device pan, tilt, and zoom (PTZ) coordinates. Machine vision enables the robot to zoom in (zero in) precisely on a scenario that was photographed before, in order to compare data to data which was previously collected, and detect differences in the data, including photos and images, over time.

Embodiments of the invention are directed to a method for data collection. The method comprises: providing a robot for moving along a controlled path, the robot including at least one sensor; moving the robot to a first location for obtaining first data associated with the first location, and then to a second location; and, moving the robot back to the first location for obtaining second data, and confirming that the robot is at the first location by: analyzing presently sensed second data, and comparing the presently sensed second data against reference data for correspondence between the second data and the reference data.

Optionally, the method additionally comprises: obtaining the second data and analyzing the second data against reference data for correspondence between the second data and the reference data.

Optionally, the method is such that the reference data includes the first data.

Optionally, the method is such that the correspondence between the data is based on reference points.

Optionally, the method is such that the data includes one or more of: images, light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, and, motion detection.

Optionally, the method is such that the correspondence is between one or more reference points in the second data and the reference data.

Optionally, the method is such that the reference points include portions of second data and the reference data.

Optionally, the method is such that the at least one sensor includes one or more of: a camera, and detectors for at least one of light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, and,

motion detection.

Optionally, the method is such that the controlled path includes at least one of a track or a rail.

Optionally, the method is such that the robot is moved by signals from a controller remote from the robot.

Optionally, the method is such that the first location is a preset, and the preset includes a position of the robot in space.

Optionally, the method is such that the at least one sensor includes a camera for capturing images, and the preset location includes at least pan, tilt and zoom (PTZ) position of the camera.

Embodiments of the invention are directed to a system for data collection. The system comprises: a robot for moving along a controlled path, the robot including at least one sensor; and, a processor. The processor is programmed for: moving the robot to a first location for obtaining first data associated with the first location, and then to a second location; and, moving the robot back to the first location for obtaining second data, and confirming that the robot is at the first location by: analyzing presently sensed second data, and comparing the presently sensed second data against reference data for correspondence between the second data and the reference data.

Optionally, the system is such that the at least one sensor includes one or more of: a camera, and detectors for at least one of light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, and, motion detection.

Optionally, the system is such that the controlled path includes at least one of a track or a rail.

Optionally, the system is such that the robot is moved by signals from a controller remote from the robot.

Optionally, the system is such that the first location is a preset, and the preset includes a position of the robot in space.

Optionally, the system is such that the at least one sensor includes a camera for capturing images, and the preset location includes at least pan, tilt and zoom (PTZ) position of the camera.

This document references terms that are used consistently or interchangeably herein. These terms, including variations thereof, are as follows.

A “computer” includes machines, computers and computing or computer systems (for example, physically separate locations or devices), servers, computer and computerized devices, processors, processing systems, computing cores (for example, shared devices), and similar systems, workstations, modules and combinations of the aforementioned. The aforementioned “computer” may be in various types, such as a personal computer (e.g., laptop, desktop, tablet computer), or any type of computing device, including mobile devices that can be readily transported from one location to another location (e.g., smart phone, personal digital assistant (PDA), mobile telephone or cellular telephone).

A “server” is typically a remote computer or remote computer system, or computer program therein, in accordance with the “computer” defined above, that is accessible over a communications medium, such as a communications network or other computer network, including the Internet. A “server” provides services to, or performs functions for, other computer programs (and their users), in the same or other computers. A server may also include a virtual machine, a software based emulation of a computer.

An "application", includes executable software, and optionally, any graphical user interfaces (GUI), through which certain functionalities may be implemented.

Unless otherwise defined herein, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein may be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

BREIF DESCRIPTION OF THE DRAWINGS

Some embodiments of the present invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

Attention is now directed to the drawings, where like reference numerals or characters indicate corresponding or like components. In the drawings:

FIG. 1 is a diagram of an exemplary environment for the system of the present invention;

FIG. 2A is a diagram of an Enterprise Resource Planning (ERP) module of FIG. 1;

FIG. 2B is a diagram of the robot system as part of the system of FIG. 1;

FIG. 2C is a diagram of an another robot system as part of the system of FIG. 1;

FIGs. 2D-1 to 2D-4 are perspective views of the robot of the robot system of FIG. 2C, on a rail (FIGs. 2D-1 and 2D-2) and without the rail (FIGs. 2D-3 and 2D-4);

FIG. 2E is a diagram of the robot of FIG 2C having moved along the rail to a new location or PRESET from that of FIG. 2C;

FIG. 2F-1 is a diagram of definitions used in the flow diagram of FIG. 2F-2;

FIG. 2F-2 is a flow diagram detailing an example process performed by the robot of FIGs. 2C, and 2D-1 to 2D-4;

FIG. 2F-3 is a diagram of position correction from the flow diagram of FIG. 2F-2;

Fig 2F-4 is a flow diagram of another process performed by the robot of FIGs. 2C, and 2D-1 to 2D-4;

FIGs. 2G-1 and 2G-2 detail example processes performed by the robot of FIGs. 2C and 2D-1 to 2D-4;

FIG. 3 is a block diagram of an Artificial Intelligence (AI) engine as part of the system of FIG. 1;

FIG. 4A is a diagram of a Rotating Field System (RFS) in accordance with embodiments of the invention;

FIG. 4B-1 is a diagram of a Nutrient Film Technique (NFT) system in accordance with embodiments of the invention;

FIG. 4B-2 is a top view of the a portion of the NFT system of FIG. 4A;

FIGs. 5A and 5B are diagrams of a hammer system in accordance with embodiments of the present invention; and,

FIG. 6 is a flow diagram for a process performed by the hammer system of FIGs. 5A and 5B.

This document includes Appendices: Appendix A (Four Pages), Appendix B (Nine Pages), Appendix C (Six Pages), and Appendix D (Thirty-four Pages), which are attached.

DETAILED DESCRIPTION OF THE DRAWINGS

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings. The invention is capable of other embodiments or of being practiced or carried out in various ways.

As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method or computer program product. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more non-transitory computer readable (storage) medium(s) having computer readable program code embodied thereon.

Throughout this document, references are made to directions, such as upper, lower, proximal, distal, upward, downward, top, bottom and derivatives thereof. These directional references are for example, only, in order to describe the various systems, machines and apparatus in an example operation, and are not otherwise limiting.

The present invention is directed to computerized, and automated, control of systems associated with greenhouses, farms and the like, but is not limited thereto. The systems and methods disclosed herein are used in controlling and managing performance of greenhouses, farms and the like, from seeding through harvest. The invention also provides a system which includes a data collection robot, which collects large amounts of data, and stores it, for example, using structured query language (SQL). The data collected and stored includes, for example, images in the visual spectrum, infrared (IR) or ultraviolet (UV) spectrums, sounds of any kind including ultrasounds or any other data that can be detected. The data analysis uses, for example, artificial intelligence (AI) learning and comparison procedures, in order to draw conclusions as to the control of the site or system, to improve and/or maximize performance.

FIG. 1 shows an exemplary system 100, an agricultural system, which, for example, employs hydroponics, in accordance with the invention. The system includes a controller 102 which is linked to a communication bus 104 (representative of multiple communication busses), which is in turn, linked to sensors for units 106 of plants (U_1 to U_m, with “m” being the last of the units), and

greenhouses 108 (H_1 to H_n, with "n" being the last of the greenhouses). The controller 102 also links to a robot 110 for data collection and a hammer system 112. The controller 102 also links to a network(s) 50.

The network(s) 50 is, for example, a communications network, such as a Local Area Network (LAN), or a Wide Area Network (WAN), including public networks such as the Internet. The network(s) 50 may also be a combination of networks and/or multiple networks including, for example, cellular networks. The network(s) 50, although shown as a single network, may be a combination of networks and/or multiple networks including, for example, in addition to the Internet, one or more cellular networks, wide area networks (WAN), and the like. "Linked" as used herein includes both wired and/or wireless links, connections, and the like, either direct or indirect, and placing the computers, including, servers, components and the like, in electronic and/or data communications with each other.

The units (U) 106 include Rotating Field System (RFS) conveyers, such the example RFS 116a shown in FIG. 4A and, for example, as shown and described in commonly owned US Patent No. 9,848,544, entitled: Automated Hydroponic Greenhouse Factory, the disclosure of which is incorporated by reference in its entirety herein. Other units (U) 106 include Nutrient Film Technique (NFT) Conveyers 116b, and other growing beds 116c (including growing beds using conventional and hydroponic techniques). Each of the units 116a, 116b, 116c may include a hammer system 112, of individual hammer system units 112x.

The sensor command lines/communication bus 104 supports sensors, such as those for: electrical conductivity (EC), pH, temperature, oxidation-reduction potential (ORP), x-ray spectroscopy (using an x-ray spectrometer for performing elemental analysis by Energy Dispersive X-ray Fluorescence (EDXRF) or Wavelength Dispersive X-ray Fluorescence (WDXRF)), and vision/imaging (cameras, imaging, and image processing apparatus). The command lines 104 include electrical lines, and typically, also include fiber optic lines and convertors, repeaters, wireless communication transmitters, filters and Remote input/output (I/O) (RIO) integrated boards with a Central Processing Unit (CPU) and memory. The RIOs are also designed to perform local control tasks without having to send the information to the controller 102 and wait for a response. This allows for fast response time, in situations such as switching a conveyer ON and waiting for it to start (respond) within milliseconds.

The controller 102 includes various processors, such as a central processing unit (CPU) 119a, including microprocessors, and other computer components. The CPU 119a is in electronic and/or data communication with storage/memory 119b. The controller 102 also includes a classifier 120, a filter 122, and database(s) 124. These components 120, 122 and 124 are linked to and interact with a fertilizer module 130, a climate control module 132 and an Enterprise Resource Planning (ERP) module 134. The term "module" includes a component for storing instructions (e.g., machine readable instructions) for performing a process, and including or associated with processors for executing the instructions.

The controller 102 includes a graphical user interface (GUI) 140, through which a user 141 can interact with the controller 102 and control the system 100, both locally, and remotely, over the network(s) 50.

The CPU 119a links to the components 120, 122, 130, 132, 134, 140 of the controller 102. The CPU 119a and storage/memory 119b, are linked, and are linked to the components 120, 122, 130, 132, 134, 140, such that all of the aforementioned components are linked to each other, either directly or indirectly. These components operate in conjunction with the CPU 119a and storage/memory 119b to perform the processes (methods) of the present invention.

For example, the processors of the CPU 119a may include x86 Processors from AMD (Advanced Micro Devices) and Intel, Xenon® and Pentium® processors from Intel, as well as any combinations thereof. Additional processors, including hardware processors, storage/memory, modules and storage media may also be part of the system for performing the invention.

The storage/memory 119b stores machine-executable instructions executed by the CPU 119a for performing the processes of the invention, as detailed below. The storage/memory 119b, for example, also provides temporary storage for the controller 102.

The fertilizer module 130 monitors and controls fertilizer dosing, based on sensed parameters in the units 106, including, for example, electrical conductivity, pH, temperature, Oxidative Reduction Potential, x-ray spectroscopy (XRS or XRF), and vision/imaging. EC (Electrical Conductivity) represents the total amount of dissolved solids (TDS) in the water (e.g., nutrient solution), the solids corresponding to the fertilizer. EC measurements provide a good evaluation of TDS. By providing a small and fixed amount (DOSE) of fertilizing solution followed by time for this amount to mix with the water in the unit (U), the system allows reaching a set point accurately without over-dosing.

The dose is determined by the volume of water in the unit (U) and the biomass cultivated. The fertilizing solution is comprised of at least one fertilizing mixture. The pH is such that the desired level is defined by two set points, above and below an average or normal pH. pH is monitored and corrected either by addition of acid or by an addition of base. The same "dose" sequence is applied adding only a dose of acid or base at a time and allowing it to mix in before measuring again. The ORP of the solution allows better control of microbial growth. This is measured with an electrode and monitored by injection of solution. The same "dose" sequence is applied adding only a dose of the solution at a time and allowing it to mix in before measuring again. Flow diagrams for fertilization processes performed by the fertilizer module are provided as Appendix A, attached hereto.

The climate module 132 functions to control the climate, typically in terms of one or more of temperature, humidity and light, in each greenhouse H 108. Cooling the greenhouse H 108, for example, is done by passive ventilation (opening windows) and active ventilation (fans). The process provided in Appendix B, attached hereto, applies data, sensed from ambient temperature sensors 108a, wind speed and wind direction, and controls the operation of fans and the opening of windows of the particular greenhouse H (which windows to open so as to create airflow in a given direction).

The ERP module 134 provides logs of the number of plants, or batches of plants, in each section of the greenhouse (sections may be of different size), its variety, when each plant was planted (seeded), all transplants of the plant, fertilizer amounts used for each plant, plant location greenhouse/unit, plant status (stage of production) and projected harvest time. This data for each plant, or batch of plants, is used, for example, to create recommendations on when to order more seeds and how much stock will be available for sale at any given day. As the number of plants and, thus, the data increases, the classifier 120 may be trained with this data to forecast plant growth, from seeding to harvest.

FIG. 2A shows the ERP module 134, which can be synchronized with any external accounting system and generate purchase orders for raw materials, such as seeds, fertilizer, and the like, and create production forecasts.

All data from the Fertilizer module 130, the climate control module 132 and ERP module 134 is sent to the database(s) 124. Data is also sent to the database(s) 124 from the robot 110 and the hammer system 112, with individual hammer units 112x. This data from the databases 124 is filtered by the

filter 122. The filtered data is received by the classifier 120, for example, in response to a request from the classifier 120 based on the objective function the classifier 120 is to perform.

The classifier 120 analyzes the given received data, as input, in accordance with one or more objective functions. Objective functions for the classifier 120, for example, include: maximum profits; maximum revenues; maximum plant yield (weight based); maximum nutritional value of the plants; minimal water usage; and, minimal fertilizer usage.

As shown in FIG. 2B, the robot 111 of the robot system 110 is, for example, shown as a block diagram. The robot 111 is, for example, a rail/line riding or autonomous robot, equipped with devices, such as cameras 150, video displays, microphones, sonic detectors, and speakers, to enable viewing the plants and workers in real time, and to assist in detection of problems that cannot be detected solely through the system 100. The robot 111 provides interaction between with the greenhouse workers and the controller 102, via the robot input/output (RIO) module 152. The motion of the robot 111 is controlled by a motion controller 154, which can be either controlled by an expert in the control center, via the GUI 140, or remotely, over the network(s) 50, via WiFi® transceivers 156, 157 on the robot 111 and controller 102, respectively. The robot 111 is powered by a power source 158, such as a battery.

The robot 111 functions by gathering data on the normal patterns of the farm (via thermal or sonic imaging) and will be able to detect abnormalities. For example, a burst in a pipe may be viewed as a cold spot in thermal imaging. An inner clog in a pipe will lead to plant dehydration, which may be detected by a rise in temperature of the plants in the affected area. Insect infestation can be detected by sonic detectors. The robot 111 is also programmed to sound an alarm, or signal a communication to an operator, via the GUI 140 or over the network(s) 50 that attention is needed.

Reference is now made to FIGs. 2C to 2G-2, which shows another robot system 110', suitable for use as the robot system 110 of FIG. 1.

FIG. 2C shows an exemplary operating environment, includes the network(s) 50, to which is linked the controller 102 or a host computer 1100 and/or a host server (e.g., which directly links to the network 50), and a robot 1110. The robot 1110, for example, also links to a WiFi® device 1102, to link to the network 50 (to be under the control of the controller 102, via WiFi®, radio signals, infrared signals, or the like, or a host computer 1100). While the controller 102 and its operation of

the robot system 110' is detailed below, the description provided for the controller 102 is also applicable to the host computer(s) 1100.

The controller 102 supports the robot system 110', either alone or with other, computers, including servers, components, and applications, for controlling the robot 1110 and preforming various processes in accordance with the invention. There is also storage 1120, for example "cloud storage", linked to the network(s) 50, and associated with the controller 102. The controller 102 may, for example, also include an auxiliary host computer/host server 1100a, from which the robot 1110 and the system 110' can be controlled. The robot 1110 functions, for example, as a data collection robot.

Remaining in FIG. 2C, the robot 1110 moves along a rail 1150, which is for example, a controlled path for the robot 1110. The rail 1150 may also be single or multiple tracks and/or guides. The rail 1150 is positioned proximate to growth areas 1152 for plants, crops and the like, as well as irrigation channels 1154, which supply water and nutrients to/from the respective growth areas 1152.

FIGs. 2D-1 to 2D-4 show the robot 1110, with FIGs. 2D-1 and 2D-2 showing the robot 1110 as it is movably mounted along the rail 1150. The rail 1150 is in turn, mounted to a wall ceiling or the like, by suspension 1202. The rail 1150 includes a base 1150a, and a track 1150b, supported by supports 1150c extending from the base. The rail 1150b supports wheels 1204a, 1204b of the robot 1110. The wheels 1204a, 1204b attach to a crossbar 1205 via an arm 1206, which connects to the robot 1110. At least one wheel 1204a is powered by a motor 1204M, under control of a motor driver 1211. The motor driver 1211 is controlled by a reconfigurable input output RIO microprocessor (RIO) 1207 that receives orders from the robot controller (CON) 1208 which, for example, serves as a main computer for the robot 1110. The RIO 1207 is, for example, a printed circuit board that has a programmable microprocessor plus input and output ports, either digital or analog. For example, the RIO 1207 is connected by means of serial communication (Universal Serial Bus (USB) and the like) to the robot controller 1208, to transmit and obtain these inputs and outputs from dedicated software. Support rollers 1209 on the arm 1206, which are, for example, spring biased, contact the rail base 1150a for easing the robot's 1110 movement along the rail 1150. The RIO 1207 is controlled, for example, by the robot controller 1208.

The robot controller (CON) 1208 also controls the imaging device, e.g., camera 1210, of the robot 1110, including the images, taken and time stamps therefore, image processing, as well as camera location, including track location as well as positioning of the PTZ and the PTZ coordinates for the

camera lens associated with track location, defining each “preset”. The controller 1208 also includes a processor, for processing signals received from the network(s) 50 (and received in a transceiver on the robot 1110), as well and sending signals, images and the like, via the transceiver on the robot 1110 to the controller 102 (or host computer 1100). The camera 1210, motor 1204M and controller are receiving power from a power supply, such as a battery 1214.

While a camera 1210 is shown, the robot 1110 may also include, in addition to or instead of the camera 1210, one or more of multispectral cameras (which, for example, operate as image sensors), sensors (e.g., light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, motion detection, sound), microphones and other audio equipment, and, pesticide dispersion units, such as sprayers.

The robot 1110 is designed for collecting large amounts of data, for example, images, thermal readings, such as temperature, pressure, and light conditions, and sounds, and store this data in a database 124 using, for example, Structured Query Language, SQL. The robot 1110 is programmed to return to the same location along the rail 1150 and collect data, including taking images from this exact same location (position in space, for example, expressed by coordinates), the exact same location known as a “preset”. This “preset” is the exact same location on the rail 1150, the same PTZ and the same region of interest (ROI), allowing to focus on specific portions of the image, which are of interest. For example, by focusing on a certain portion of each image from the preset, taken at different times, plant growth, fast, normal or slow, can be detected, as can be color, such as a lack of green or various shades of green being indicative of plant health, or color, indicative of plant health, soil conditions, nutrient conditions and absorption into the plant, insect and pest infestations, and the like.

The robot 1110 is such that it can repeat the same picture at every desired time period, such as every hour, day or every week, or at intervals, both regular and random. This allows for analysis by comparing images, for learning, e.g., artificial intelligence, and making decisions, e.g., increasing/decreasing sunlight exposure. The robot 1110 is programmed to "get back" or return to the same place. This is performed by computer analysis of "reference points" (for example, from previous images which serve as reference images, or known points, such as structures, landmarks and the like) in order to "fine tune" and adjust the “preset.” The computer analysis, for example, employs comparisons and/or looking for correspondence between data (data sets), including reference points in the data being compared and analyzed. The processes for operating the robot

1110 include algorithms, and are such that the robot 1110 can return to each desired "preset" and collect data including images from each desired "preset" for data collection. The procedure of returning to a desired preset is performed before images are taken and stored. As a result, at a later time and/or with another computer, the images and data are analyzed, for example, by comparisons and/or looking for correspondence between data (data sets), including reference points therein, allowing for decisions to for better greenhouse factory operation.

FIG. 2E shows the robot 1110 having moved to a location along the rail 1150 in FIG. 2C to the location on the rail 1150, known as a "preset", where a region of interest (ROI), represented by the location X, in the growth area 1152. This preset is a location in space, defined by parameters, including the location of the robot 1110 along the rail 1150, the Pan, Tilt, Zoom (PTZ) of the robot camera 1210 to focus on the ROI, the ROI location, and reference points at the ROI, as defined in the process definitions of FIG. 2F-1.

The robot 1110 is such that it must return to the exact preset, for example, on multiple occasions, at regular or random intervals, such as every hour, every day, or other preset time, in order to obtain an image of a ROI, as well as sample environmental parameters, such as temperature, air quality and the like. By returning to the exact preset, the robot 1110 can perform repeated operations, necessary for data collection and analysis, as detailed below.

The robot 1110 returning to the exact preset involves a process formed by two subprocesses, and is shown in the flow diagram of FIG. 2F-2. The first subprocess is a mechanical positioning process, and the second subprocess is an optical positioning/repositioning process based on software, to correct the position of the robot and/or the camera and its PTZ orientation (coordinates). This second subprocess includes a frame grabbing procedure to fine-tune the data capture position and angle of capture, by identifying data parts that are known to be in a specific location, e.g., from reference images or established structures, landmarks, and the like, in order to repeatedly determine robot 1110 and camera 1210 (and sensor) positions and camera 1210 (and sensor) angles. increase the position and angle These subprocesses are, for example, performed automatically and in real time.

The process, as per the flow diagram of FIG. 2F-2 includes the following terms (also listed in FIG. 2F-1):

HOME – a location on the rail 150 with an ID (Identifier) location. Each HOME has a unique ID location;

PRESET – a point with definitions of:

- Spatial coordinates in space, e.g. location on the rail
- PTZ values.
- At least one reference points, defined for example by a rectangle in the frame.
- ROI, defined for example by a rectangle in the frame

TIME INTERVAL – The time delay between PRESET #N to

PRESET #(N + 1)

PROCEDURE - A group of presets, each one with specified tasks, which are executed successively. The time between two consecutive presets is the "Time interval".

SCHEDULE – Defines the timetable to perform the procedures.

REFERENCE POINT IDENTIFICATION – An image analysis subprocess that compares an obtained image to a reference image and finds the pattern of the reference point.

REFERENCE POINT IDENTIFICATION NUMBER – RPID

REFERENCE POINT IDENTIFICATION ALGORITHM – a subprocess for finding reference points in case of a major deviation in mechanical positioning. This process may include for example: returning to the nearest homing station and returning to the preset, scanning the immediate area for the reference points or another method.

ROI IDENTIFICATION ALGORITHM - a sub process for finding the ROI after the reference points have been identified, in case of a minor deviation in mechanical positioning. This process may include for example, a mechanical movement correction that will include the ROI in the frame.

Returning to FIG. 2F-2, the process shown is an example process for data collection. Initially, at block 1402, parameters are set, and include, for example, positioning, a time interval, and a task such as color analysis, clogging analysis, growth comparison and analysis, and the like. At block 1404, an outputs driver is set and includes robot positioning and PTZ orientations and settings.

The process moves to block 1406, where the robot 1110 position is determined. If the robot 1110 is at the PRESET location, the process moves to block 1410c-1, for reference points identification.

Returning to block 1406, should the robot not be at the preset position, the process moves to block 1410, where the mechanical positioning subprocess is performed. Initially, the motor 1204M moves

the robot 1110 to the PRESET location, at block 1410a-1. If the robot 1110 has not reached this location, the process moves to block 1410a-2, where the X, Y, Z coordinate positioning, (here the rail 1150 is one dimensional so as to be an X coordinate), and defining a position location. This process repeats until the PRESET location is attained, and once attained, the process moves to block 1410b-1. Alternately, block 1410b-1 is reached initially, should the robot initially reach the PRESET location.

Initially, at block 1410b-1 the PTZ orientation for the camera 1210 or other imaging apparatus of the robot 1110 is determined. If the correct PTZ orientation has not been reached, the process moves to block 1410b-2, where, the PTZ adjustment to the proper orientation is made, and the PTZ location is defined. This process of block 1410b-2 repeats until the correct PTZ orientation is obtained. With the correct PTZ orientation reached, the process moves to block 1410c-1. Alternately, block 1410c-1 is reached initially, should the robot 1110 initially achieve the proper PTZ camera 1210 orientation.

At block 1410c-1 one or more reference points are identified. If not, the process moves to block 1410c-2, for application of the reference points identification algorithm, and RPIDs are defined (and recorded). The process of block 1410c-2 is repeated until the reference points are identified, and RPIDs are defined. With the reference points identified and defined, the process moves to block 1410d-1. Alternately, block 1410d-1 is reached initially, should the robot 1110 initially identify and define the necessary reference points associated with the PRESET.

At block 1410d-1, it is determined whether the ROI has been identified by analysis of the reference points, for example, a correlation between the reference points from previous image against those of the present image. If the ROI needs to be defined, the process moves to block 1410d-2, for ROI identification algorithm. Once the ROI is defined, either initially, at block 1410d-1 or at block 1401d-2, the process moves to block 1412.

At block 1412, optical positioning is evaluated and the reference points in the present image are compared against those of the reference image. Since it is unlikely that the reference points of the two images coincide completely, the process moves to block 1414 where the optical positioning/repositioning sub-process occurs.

The optical positioning/repositioning process performed in block 1414 is shown in FIG. 2F-3, to which attention is now directed. Here, a reference points on a reference image 1450, are identified

and compared with corresponding identified reference points on the present image 1452. The corresponding ROI's 1450a, 1452a are then corrected, based on deviations of the reference points, making them amenable to image comparison and analysis. The optical positioning compensates for mechanical inaccuracies for achieving maximum repetition for ROI identification. From block 1414, the process moves to block 1408 to perform the preset's tasks, for example image analysis, report generation, and the like.

From block 1408, the process moves to block 1416, where the data of the image is logged, and the process returns to block 1402, from where it resumes.

FIG. 2F-4 is a general flow diagram for processes involving data collection and analysis. Initially, at block 1470, the data to be collected is defined, including, for example, data types, locations (all axes), times, scheduling, reference points, and the like. At block 1472, the robot has moved into the correct PRESET position, including the proper PTZ orientation (coordinates) to focus on the intended ROI, as defined by the process of FIGs. 2F-1 and 2F-2, so as to obtain one or more mages of the ROI. The process moves to block 1474, where a data analysis, such as those detailed below is performed, with the results provided as output, at block 1476.

The analysis is, for example, a color analysis, to detect general health, as well as a comparison of growth rates, for example, between the present growth period and a previous growth period. Also, the robot could be trained, for example, with artificial intelligence and deep learning, to perform a color analysis to detect disease, insect infestation, lack of certain nutrients, lack of water and the like. The color analysis can also be made in water/nutrient flow pathways to detect clogging, stagnancy of the fluid, and other problems, such as algae and bacteria growing in the water/nutrient solution. FIGs. 2G-1 and 2G-2 provide screen diagrams for a color analysis in accordance with the process of FIG. 2F-2.

Additional processes including algorithms for operating the robot 1110 for data collection at the desired presets is attached to this document as Appendix C.

FIG. 3 shows the artificial intelligence (AI) engine 302 including the classifier 120, the filter 122, and database(s) 124, described above. The AI engine 302 includes a training module 304, a data selection module 306, and a training database 308. The AI engine 302 can be part of the system 100, or be in the cloud 50, or be partly in the system 100 and partly in the cloud 50.

The training module 304 analyzes selected training data, as a data set, obtained by the selector 306, from the training data base 308 in order create a model for each designated objective function. The training data used for each objective function model is selected from training data from the training database 308, which in turn, obtains its data from the database(s) 124. The training module 304 analyzes all of the training data for each objective function, and creates a model for each objective function. The classifier 120 applies these objective function models to analyze data from the database 124 (as filtered by the filter 122 for the specific objective function to be analyzed), to generate an outcome for the selected objective function.

FIG. 4A shows a rotating field system (RFS) 116a. The rotating field system 116a creates a conveyor system and mechanism to automatically rotate trays 12 that bear plants in a growing bed in order to enable, planting, spacing, inspecting, treating and harvesting at the end or ends of the bed 14 (bed "A"), thus eliminating the need for walkways between the beds 14.

The example RFS system 116a is arranged so that trays 12 are rotated automatically, inside a water bed 14 (which is, for example, a pool in which the trays 12 float, as they are moved in accordance with a rotation) as the trays 12 float on a nutrient liquid solution 16 in the bed 14. The use of such flotation allows a reliable, low maintenance, cost efficient solution and eliminates the need for use of beatings, shafts, sliding mechanisms and other mechanical fixtures for causing linear motion of trays 12.

The bed 14 includes a separation barrier (not shown) that allows for two rows 18 of trays 12, one row 18 on each side of the barrier. Two pneumatic pistons 20 (Y-pistons) push respective rows 18 of trays 12 in opposite Y-directions. Prior to movement of a row 18 by Y-piston 20 of that row 18, that row 18 includes a gap 22 where one tray 12 is missing. For example, for the right-side row 18, as a row 18 is pushed by its Y-piston 20, the last tray 12, that is nearest to that Y-piston 20, is retained by a spring arm (not shown) that prevents that tray 12, and the rest of trays 12 in that row 18, from moving back as that Y-piston 20 retracts back, leaving a vacant tray-sized gap 24 adjacent to Y-piston 20.

Two other pneumatic pistons 26 (X-Pistons) then push the first tray 12 in each row 18 into the vacant gaps (not shown), causing that tray 12 to join the other row 18 of trays 12. This is followed by the two Y-pistons 20 again pushing rows 18 of trays 12 in the Y-direction, one row 18 in the opposite direction of the other row 18. Arrows 28 show the way trays 12 are thus rotated within the bed 14.

This procedure is governed, controlled, timed and synchronized by the CPU 119a of the controller 102, and, for example, can be started and stopped by the operator by pushing a switch.

While the system 116a automatically rotates trays 12 that carry the plants within the bed 14, the trays 12 do not leave the single bed 14 and are only rotated within the bed 14. The spacing can only be done manually, at one of the ends of the bed 14, during the rotation. The system 116 automatically, using the same pneumatic pistons 20, 26, both rotates trays 18 within a single bed 14 as needed and moves the trays 18 between neighboring beds in order to space the plants by inserting an empty tray 18 from a neighboring bed 14 in-between trays 18 whose plants need spacing. The spacing of the plants takes significantly less growing area as they build their biomass in their young growing stage, and thus need more growing area in their later growing stage. In order to utilize the growing area better, and increase the yields per square meter, plants are spaced differently during stages of their growth cycle.

FIGs. 4B (a partial cross section of the system 116b) and 4C show a Nutrient Film Technique (NFT) system 116b. The system 116b is supported by a base 402, which sits on a surface 404, such as the ground. The base 402 is, for example, in the form of a tray, so as to hold liquid, such as a nutrient solution. The base 402, typically includes upward protrusions 408. These upward protrusions 408 extend longitudinally, between the distal end 402d and the proximal end 402p of the base, so as to define compartments or gutters 410a-410c, for the nutrient solution. While three gutters 410a-410c are shown, any number of gutters is sufficient.

A nutrient film 420, with openings 422, for example, formed by perforations, supports plants 424, on a first or upper side 420a, with the roots 424r of each plant 424 extending through the respective opening 422, into the respective gutter 410a-410c, so as to be feed by the nutrient solution in the gutter 410a-410c. Typically, the leafs 424x of the plants 424 extend beyond the upper side 420a of the film 420, while the roots 424r are in contact with the nutrient solution in the respective gutter 410a-410c. The openings 422 are apertures of a diameter sufficient to allow the roots 424r to extend through the film 420, beyond the second or lower side 420b of the film 420. The nutrient film 420 is held, for example, in a removably attachable engagement, on a take-up reel 430, mounted, for example on a portable platform 432. The take-up reel 430 can be controlled automatically, or alternately manually by an operator 434 as shown. As the operator 434 rotates the take-up reel 430 in accordance with the direction of the arrow 430x, plants 424 are brought closer to the operator 434 for removal and/or cutting from the nutrient film 420 for transplant or harvest.

The film 420 is, for example, a polymeric film, such as polyvinyl chloride (PVC). The nutrient solution is, for example, water, or other nutrient solution used in hydroponics.

FIGs. 5A and 5B show a hammer system 112x, in particular, a hammer or hammer unit 112x, in a first position (FIG. 5A), when the hammer 502 (for example, a metal rod, also known as a "plunger") is not in contact with the irrigation pipe 504, and a second position (FIG. 5B), where the hammer 502 is in contact (a single short contact) with the pipe 504. The single short contact is instantaneous, and downward, followed by an immediately upward movement, in the direction of the double headed arrow 505, and is made to break up biofilms 506 and other materials, which have formed inside the pipe 504. If left unattended, the biofilms can grow so as to clog irrigation openings 508, in the pipe 504, such that irrigation fluids 510, e.g., water, nutrient solutions and the like, would not reach the plants 512.

The hammer system 112x is automated, such that the hammer 502 is moved into and out of contact with the pipe 504 by at least one coil (electro-magnet 514 in a housing 516). The electromagnet 514 (electromagnet coil or coil) includes a top (first) coil 514a and a bottom (second) coil 514b. The repeated strikes (impacts) of the hammer 502, for example, several times per minute - on a set sequence, break up the biofilm 506 into pieces 506x (FIG. 5B). These biofilm pieces flow with the fluids through the pipe 504 (in the direction of the arrow 518), or leave the pipe 504 at the end of the nutrient fluid circulation pathway. The system 112x allows varying the frequency of the hammer 502 strikes and their intensity. The hammer unit 112x, for example, typically mounts to the base or tray portion of a plant holding apparatus, such as the base (tray) 402 of the apparatus of FIG. 4B-1.

FIG. 6 shows a flow diagram of an example process for operating a hammer unit 112x. The process is performed, for example, automatically, and in real time.

The process begins at the START block 600. The hammer system 112x has been activated. Activation of the hammer system 112x and operation of the hammer, frequency of hammer strikes, may also be based on facility, greenhouse or farm temperatures, radiation, time of day or time of year (season). Initially, three calibrations are made. A first calibration is made for the top coil 514a time, at block 600a. A second calibration is made for delay time from the top coil 514a to the bottom coil 514b, at block 600b. A third calibration is made for the bottom coil 514b time, at block 600c.

From block 600, the process moves to block 602, where it is determined whether there is a trigger, for example, by a timer, or in response to a command provided by a system operator, or the like. If no, the process returns to block 602. If yes, the process moves to block 604.

At block 604, with the top coil 514a time calibrated (at block 600a), the top coil 514a is activated (and active) to pull up the hammer (plunger) 502. The process moves to block 606, where the top coil 514a is permitted to pull the hammer 502 upwards within a preset time. If no, at block 606, the process returns to block 604. If yes, at block 606, the process moves to block 608.

At block 608, with the delay time from the top coil 514a to the bottom coil 515b calibrated (at block 600b), the top coil 514a movement is stopped. The process moves to block 610, where the delay of the top coil 514a has met or exceeded a predetermined time (time period). If no, at block 610, the process returns to block 608. If yes, at block 610, the process moves to block 612.

At block 612, with the bottom coil 514b time calibrated (at block 600c), the bottom coil 514b is activated (and active) to pull down the hammer (plunger) 502. The process moves to block 614, where the bottom coil 514b is permitted to release the hammer 502, within a preset time, so that it moves downward, to strike the pipe. If no, at block 614, the process returns to block 612. If yes, at block 614, the process moves to block 602, from where it resumes.

The process may continue for as long as desired, until the coil 514 is turned OFF.

Appendix D, attached hereto, is an operational manual for the system 100.

Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, non-transitory storage media such as a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

For example, any combination of one or more non-transitory computer readable (storage) medium(s) may be utilized in accordance with the above-listed embodiments of the present invention. The non-transitory computer readable (storage) medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electro-magnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

As will be understood with reference to the paragraphs and the referenced drawings, provided above, various embodiments of computer-implemented methods are provided herein, some of which can be performed by various embodiments of apparatuses and systems described herein and some of which can be performed according to instructions stored in non-transitory computer-readable storage media described herein. Still, some embodiments of computer-implemented methods provided herein can be performed by other apparatuses or systems and can be performed according to instructions stored in computer-readable storage media other than that described herein, as will become apparent to those having skill in the art with reference to the embodiments described herein. Any reference to systems and computer-readable storage media with respect to the following computer-implemented methods is provided for explanatory purposes, and is not intended to limit any of such systems and any of such non-transitory computer-readable storage media with regard to embodiments of computer-implemented methods described above. Likewise, any reference to the following

computer-implemented methods with respect to systems and computer-readable storage media is provided for explanatory purposes, and is not intended to limit any of such computer-implemented methods disclosed herein.

The flowchart and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustration, and combinations of blocks in the block diagrams and/or flowchart illustration, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

The descriptions of the various embodiments of the present invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments.

The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

The above-described processes including portions thereof can be performed by software, hardware and combinations thereof. These processes and portions thereof can be performed by computers, computer-type devices, workstations, processors, micro-processors, other electronic searching tools and memory and other non-transitory storage-type devices associated therewith. The processes and portions thereof can also be embodied in programmable non-transitory storage media, for example, compact discs (CDs) or other discs including magnetic, optical, etc., readable by a machine or the like, or other computer usable storage media, including magnetic, optical, or semiconductor storage, or other source of electronic signals.

The processes (methods) and systems, including components thereof, herein have been described with exemplary reference to specific hardware and software. The processes (methods) have been described as exemplary, whereby specific steps and their order can be omitted and/or changed by persons of ordinary skill in the art to reduce these embodiments to practice without undue experimentation. The processes (methods) and systems have been described in a manner sufficient to enable persons of ordinary skill in the art to readily adapt other hardware and software as may be needed to reduce any of the embodiments to practice without undue experimentation and using conventional techniques.

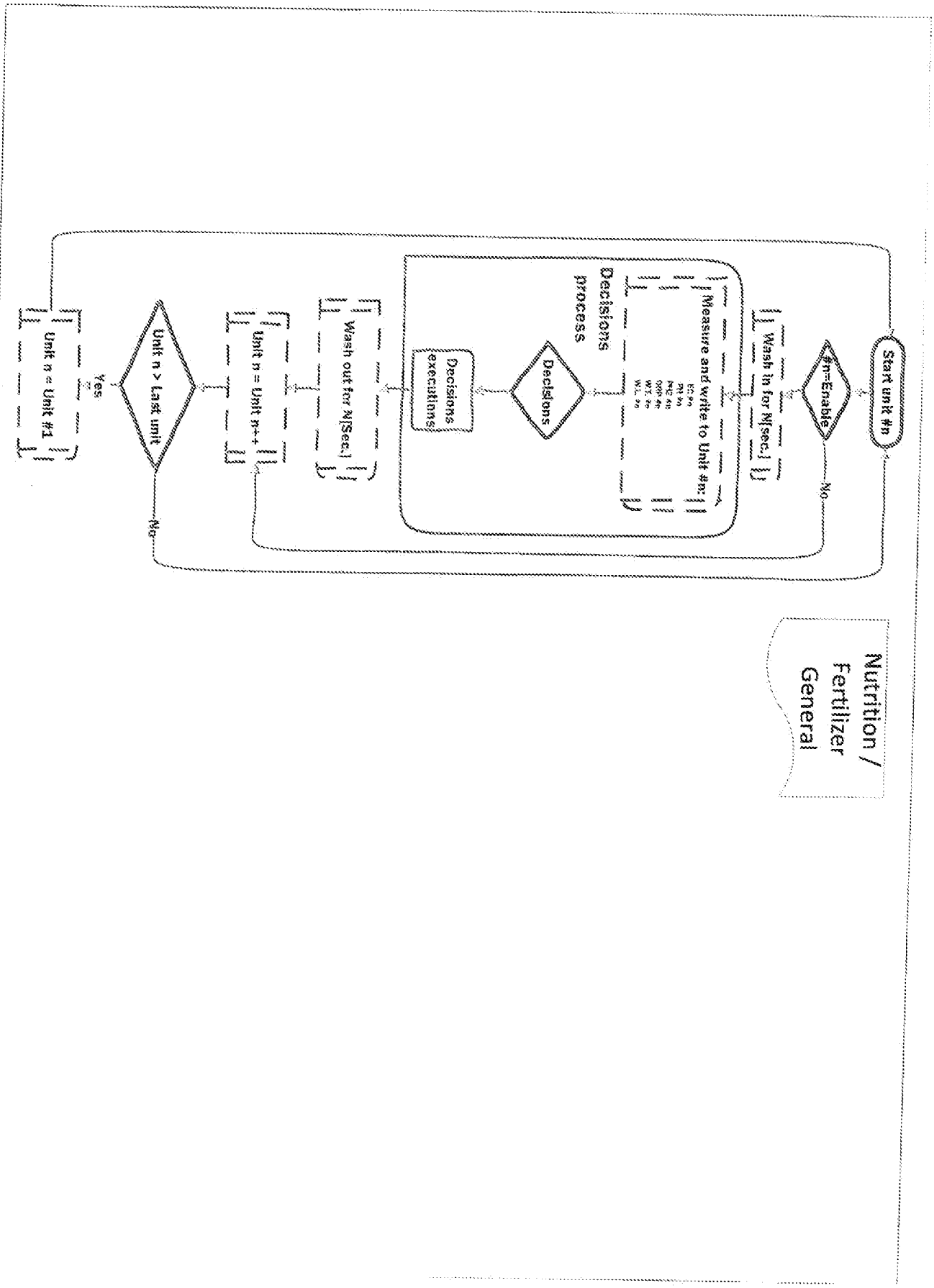
Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

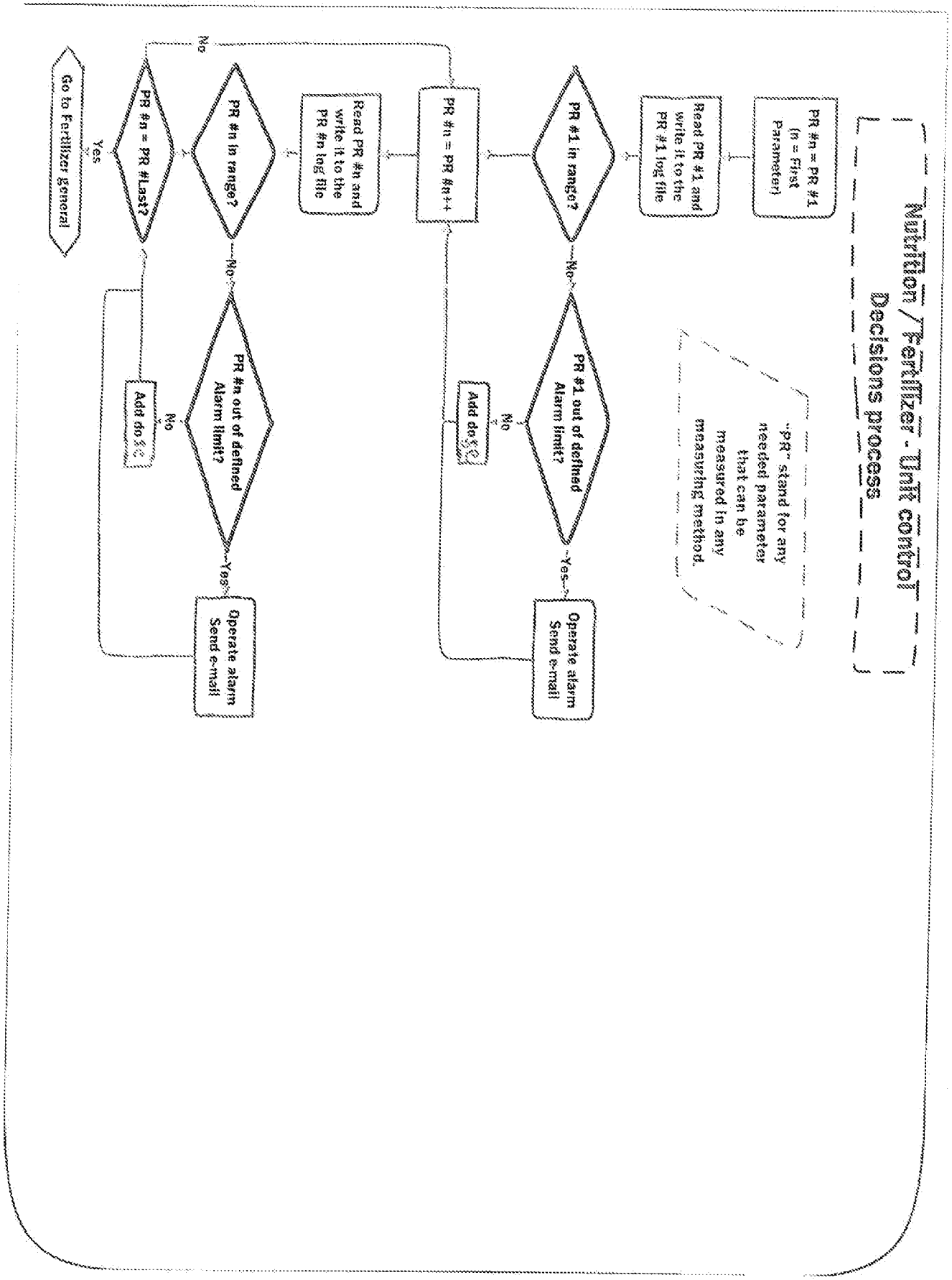
PCT Patent Application entitled: GREENHOUSE CONTROL SYSTEM

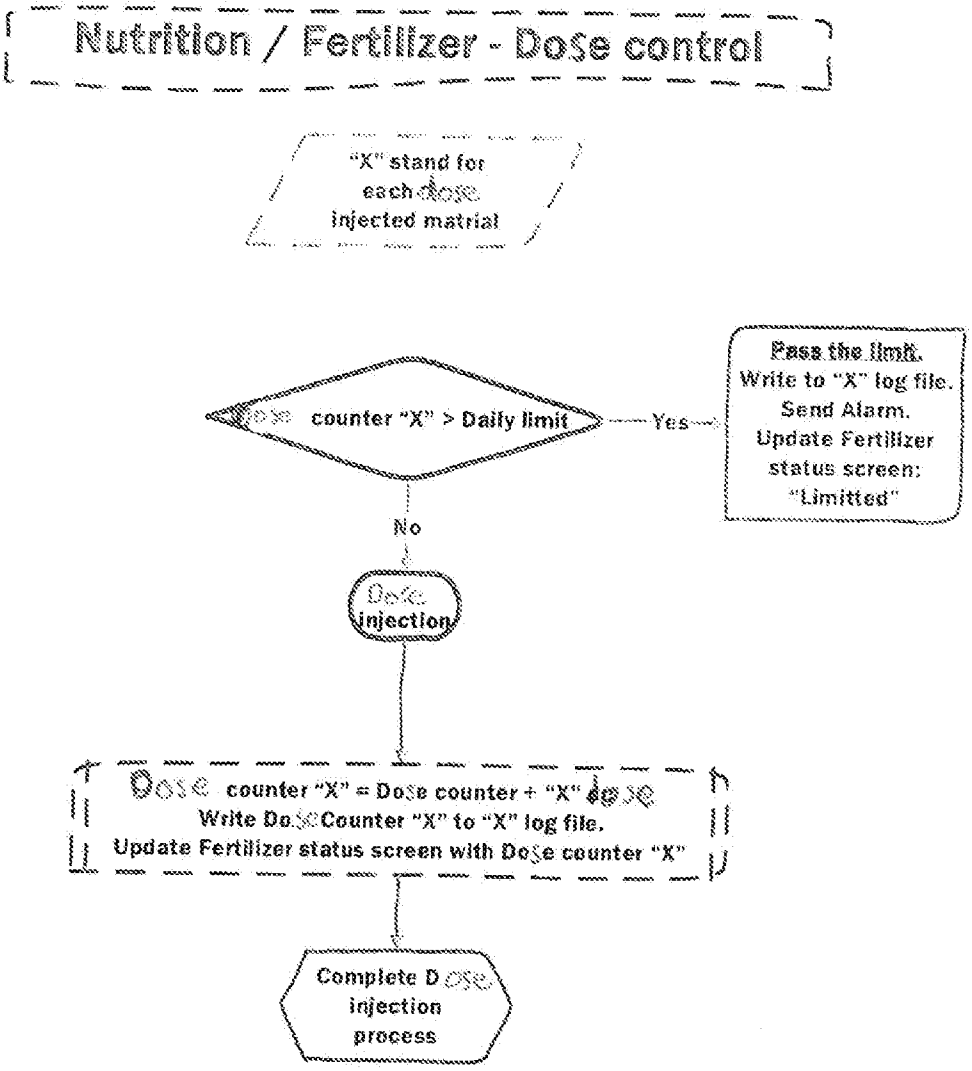
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APPENDIX A

(4 Pages Total-including this page)


Nutrition / Fertilizer General
Start unit #n
#n=Enable
No
Wash in for N[sec.]
Measure and write to Unit #n:
Decisions process
Decisions
Decisions executions
Wash out for N[Sec.]
Unit n = Unit n++
Unit n > Last unit
No
Yes
Unit n = Unit #1


Nutrition / Fertilizer - Unit control
Decisions process
PR #n = PR #1 (n = First Parameter)
Read PR #1 and write it to the PR #1 log file
"PR" stand for any needed parameter that can be measured in any measuring method.
PR #1 in range?
No
PR #1 out of defined Alarm limit?
Yes
Operate alarm Send e-mail
No
Add do $2
PR #n = PR #n++
Read PR #n and write it to the PR #n log file
PR #n in range?
No
PR #n out of defined Alarm limit?
Yes
Operate alarm Send e-mail
No
Add do $2
PR #n = PR #Last?
No
Yes
Go to Fertilizer general


Nutrition / Fertilizer - Dose control
"X" stand for each dose injected matrial
Dose counter "X" > Daily limit
Yes
Pass the limit.
Write to "X" log file.
Send Alarm.
Update Fertilizer status screen: "Limitted"
No
Dose injection
Dose counter "X" = Dose counter + "X" dose
Write Dose Counter "X" to "X" log file.
Update Fertilizer status screen with Dose counter "X"
Complete Dose injection process

PCT Patent Application entitled: GREENHOUSE CONTROL SYSTEM

Docket: 5246/18

APPENDIX B

(9 Pages Total-including this page)

Basic definitions

Process definitions:

The process inputs are Wind direction and Wind speed.
The outputs are: four windows ("N"- for North, "W"- for West, "S" - for South, and "E" - for East).
The process control has to define windows name according to the inputs.
Wind direction - Defined as ***Dir*** and Wind speed - Defined as ***WS***.
Each window (or windows) will be named according to the wind direction every cycle.
The window(s) that will be named: ***Dir*** is(are) the window(s) that the wind is coming into the greenhouse
The window(s) that will be named: ***Ndir*** is(are) the window(s) that the wind is going out from the greenhouse.
Tsetpoint define as the required temperature in the house.
Td or Tin defined as the house measured temperature.
Tx or Tout defined as the external measured temperature.
The Command: "open Win" will operate a digital output that will connect a relay to the open direction.
The Command: "close Win" will operate a digital output (different from the "open Win" output) that will connect a relay to the close direction.

If wind direction is from "N" to "S" (Dir is between 350° to 10°) open "N" as ***Dir*** and "S" as ***Ndir***.
Else if wind direction is from "NW" to "SE" (Dir is between 281° to 349°) open "N" and "W" as ***Dir*** and "S" and "E" as ***Ndir***.
Else if wind direction is from "W" to "E" (Dir is between 260° to 280°) open "W" as ***Dir*** and "E" as ***Ndir***.
Else if wind direction is from "SW" to "NE" (Dir is between 191° to 259°) open "W" and "S" as ***Dir*** and "N" and "E" as ***Ndir***.
Else if wind direction is from "S" to "N" (Dir is between 170° to 190°) open "S" as ***Dir*** and "N" as ***Ndir***.
Else if wind direction is from "SE" to "NW" (Dir is between 101° to 169°) open "S" and "E" as ***Dir*** and "N" and "W" as ***Ndir***.
Else if wind direction is from "E" to "W" (Dir is between 80° to 100°) open "E" as ***Dir*** and "W" as ***Ndir***.
Else if wind direction is from "NE" to "SW" (Dir is between 11° to 79°) open "N" and "E" as ***Dir*** and "W" and "S" as ***Ndir***.

*Each direction has to be a parameter that can be changed (for example "N" can be wider band and be change from the band 350° to 10° to the band 340° to 20° and so on for all the defined directions.



1. **Dir Definition:**
The degree offset of each sky direction. For example - Dir Definition = 10. N=350-10, E=80-100, S=170-190, W=260-280. Further information can be found in the Directions Definitions Page.

2. **Temperature Setpoint – (TS):**
The temperature value that defined as the optimum temperature value to a specific Green House.

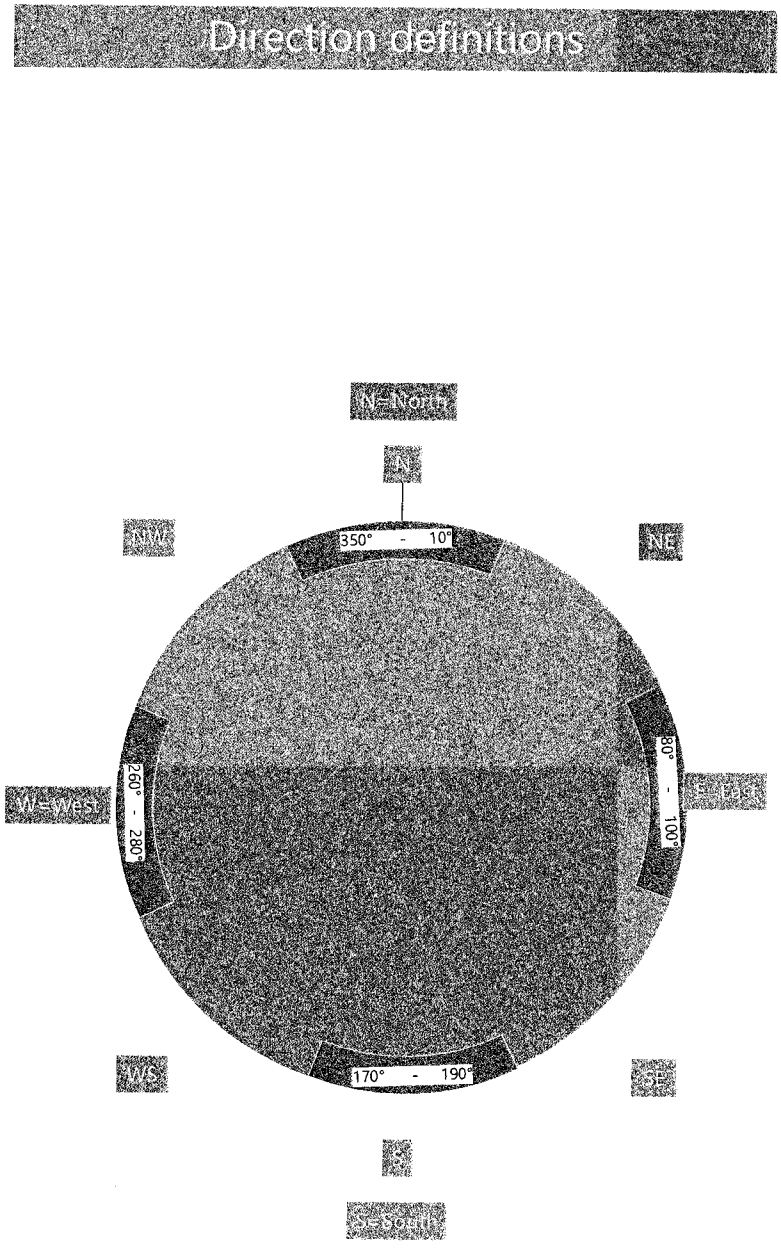
3. **Delta Temperature – (DT):**
Delta Temperature defines as DT is the difference of temperature from the Set Point Temperature and is used to define the stages to change system status.

4. **Wind Speed – (WS).**

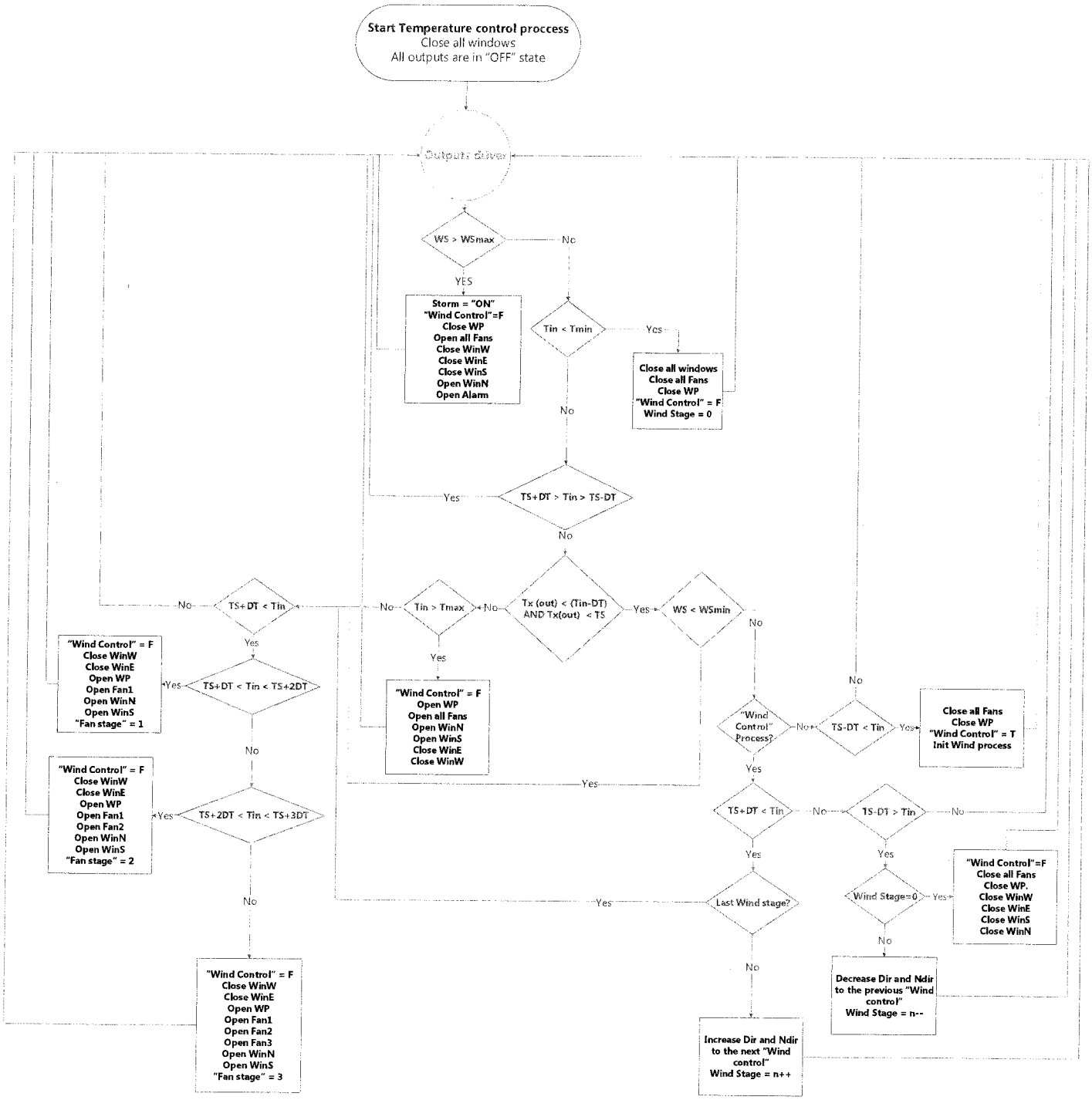
5. **Temperature inside the Green House (Tin).**

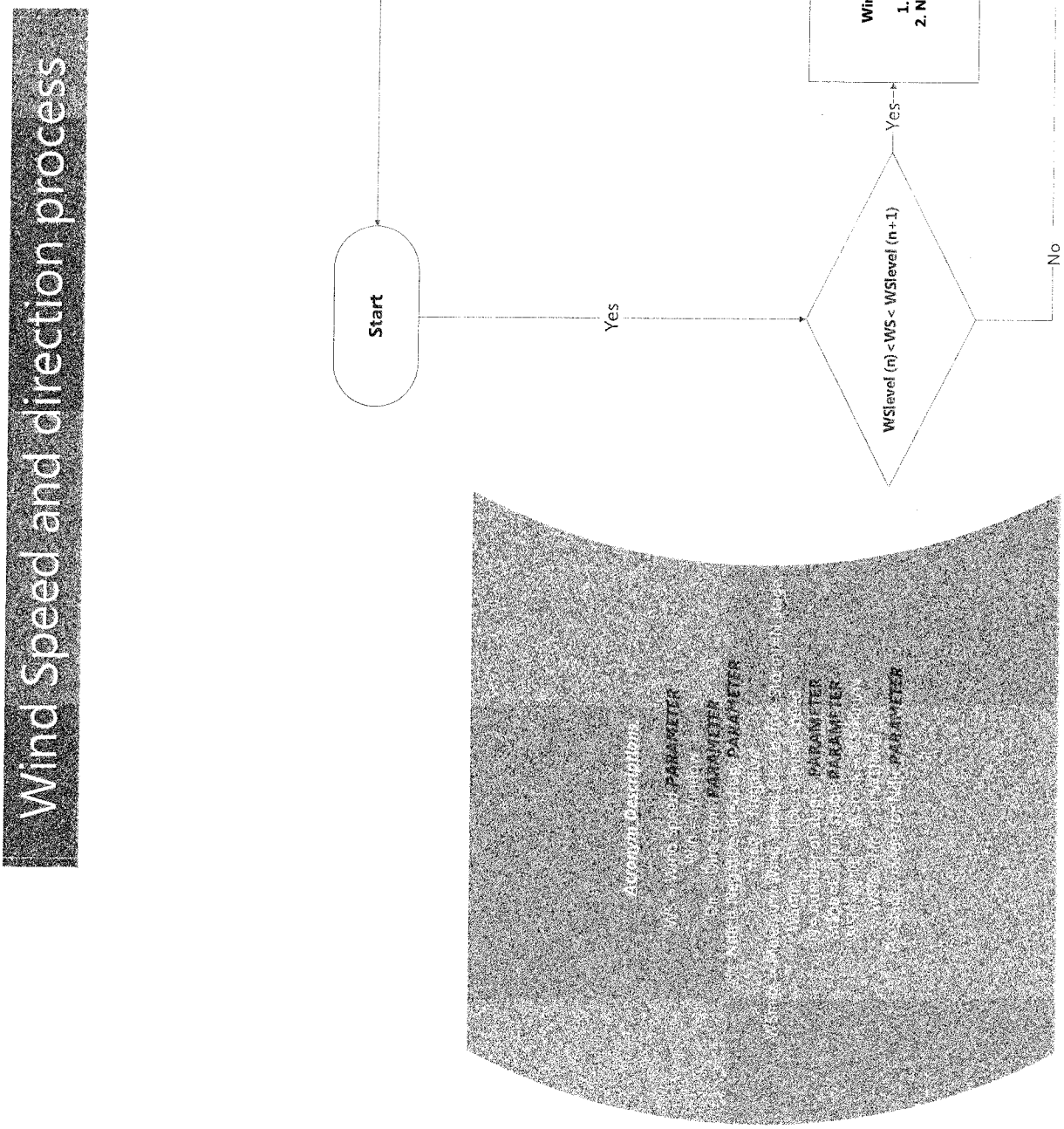
6. **Temperature outside the Green House (Tx).**

7. **Wet Pad (WP).**

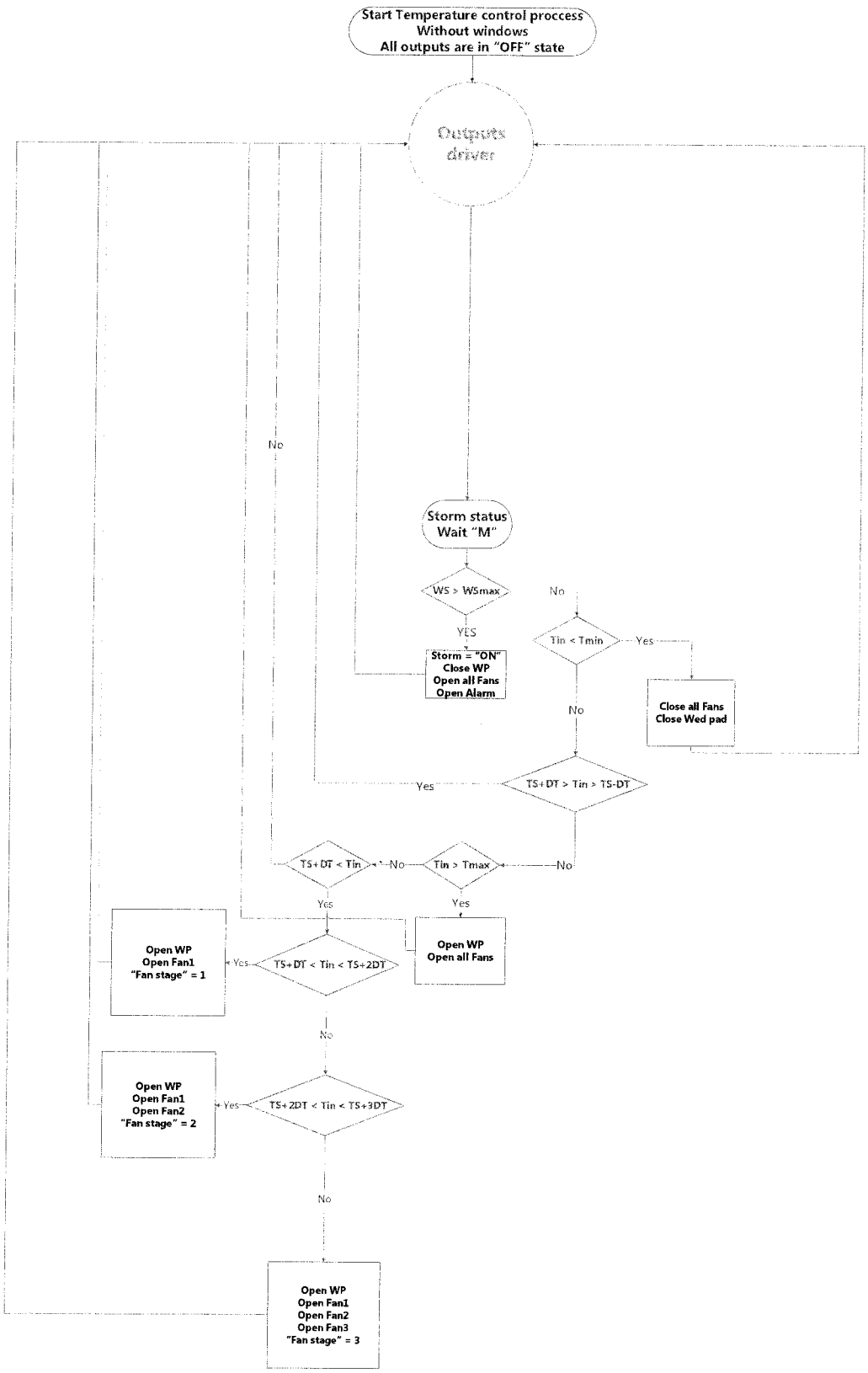

Direction definitions
N=North
N
NW
NE
350° - 10°
80° - 100°
E=East
W=west
260° - 280°
WS
SE
170° - 190°
S
S=South

Main Windows process control

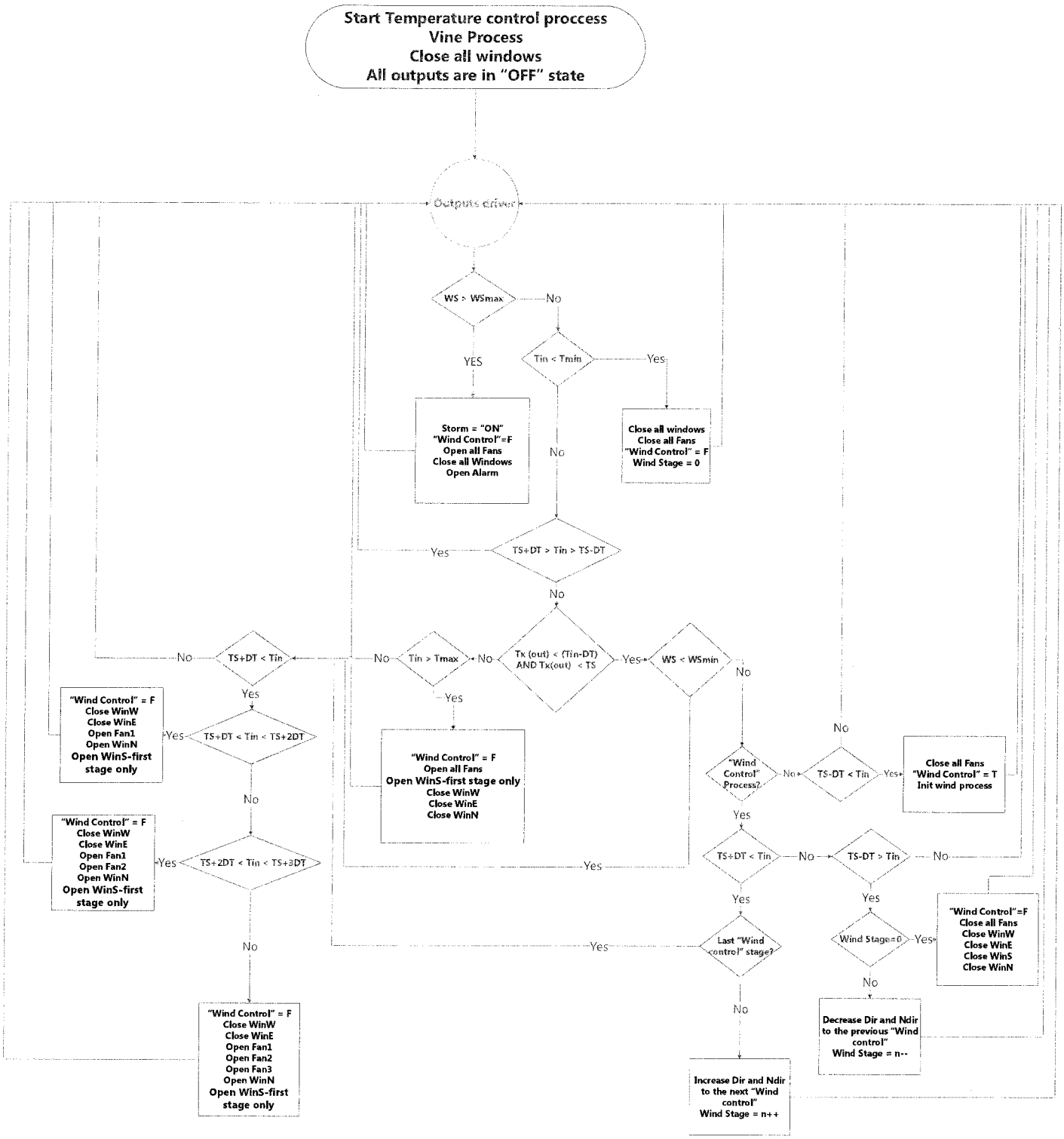


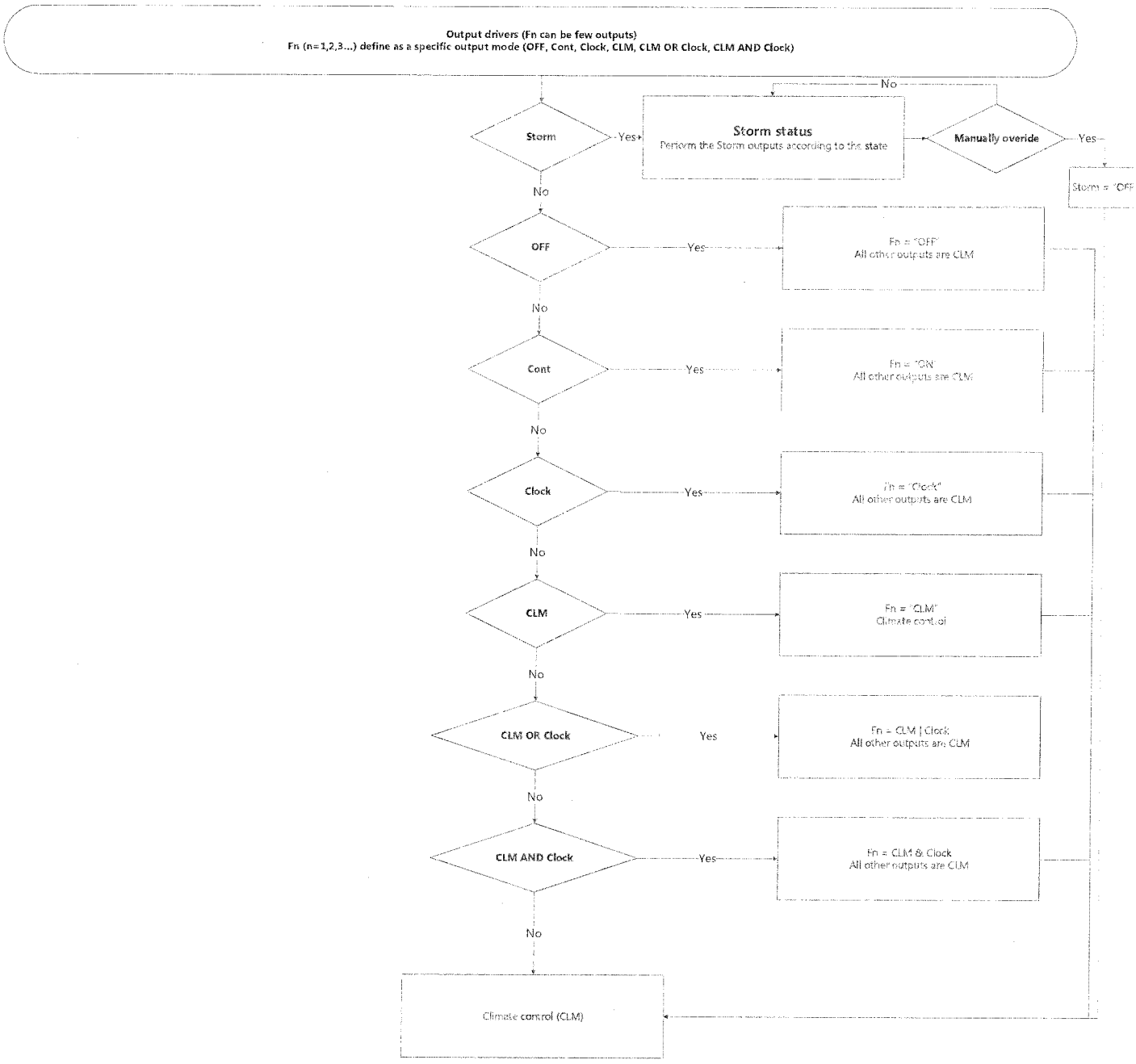

Wind Speed and direction process
Start
Yes
WSlevel (n) < WS < WSlevel (n+1)
Yes
No
Wind stage #n
1. Dir =Dirn
2. Ndir =Dirn-D

Green house without windows process



Vine process 35




Output drivers (Fn can be few outputs)
Fn (n=1,2,3...) define as a specific output mode (OFF, Cont, Clock, CLM, CLM OR Clock, CLM AND Clock)
Storm
Yes
Storm status
Perform the Storm outputs according to the state
No
Manually overide
Yes
No
OFF
Yes
Fn = "OFF"
All other outputs are CLM
No
Cont
Yes
Fn = "ON"
All other outputs are CLM
No
Clock
Yes
Fn = "Clock"
All other outputs are CLM
No
CLM
Yes
Fn = "CLM"
Climate control
No
CLM OR Clock
Yes
Fn = CLM | Clock
All other outputs are CLM
No
CLM AND Clock
Yes
Fn = CLM & Clock
All other outputs are CLM
No
Climate control (CLM)

PCT Patent Application entitled: GREENHOUSE CONTROL SYSTEM

Docket: 5246/18

APPENDIX C

(6 Pages Total-including this page)

Testview
Test System Integration

שם מסמך:	ארכיטקטורת תוכנה – רובוט GP			
מס' מסמך:	QD 001	מהדורה:	00	עמוד 3 מתוך 7

Contents

1. Generic 4
1.1. General Structure of the Growponics LabVIEW project 4
1.2. Typical Hardware Module Structure 5
1.3. Project Scheduler Engine Structure 6
2. The Grwponics Application Folders Tree Structure 7

Testview Test System Integration				
	GP ארכיטקטורת תוכנה – רובוט			שם מסמך:
עמוד 4 מתוך 7	00	מהדורה:	QD 001	מס' מסמך:

Growponics Software Architecture

1. Generic

This document summerizes the software architecture of the Growponics project.

1.1. General Structure of the Growponics LabVIEW project

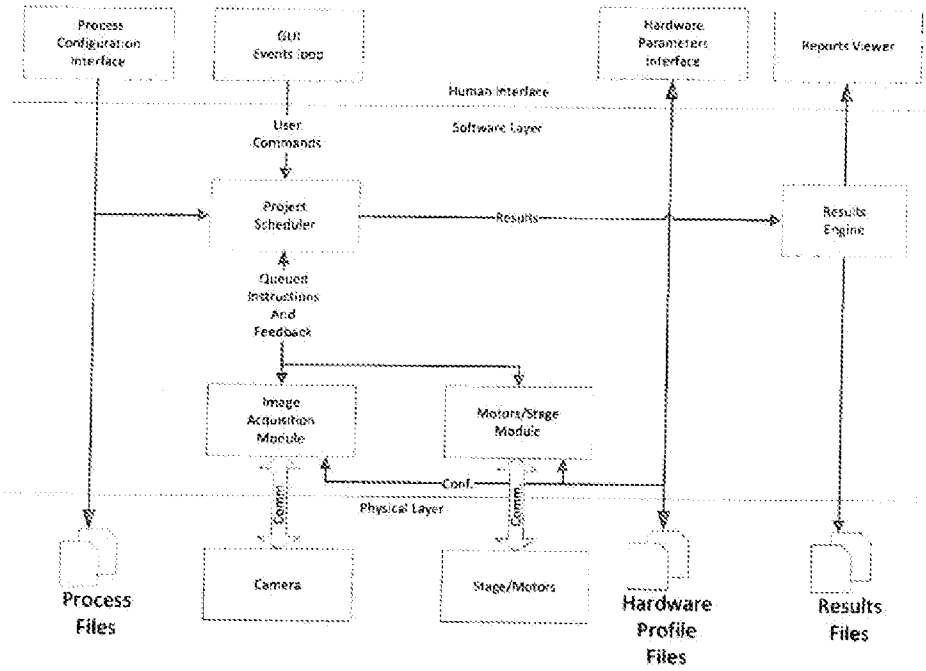


Figure 1. Generic LabVIEW Project Software Architecture

In figure 1 a generic LabVIEW project is presented with the following elements:

1.1.1. Prject Scheduler – A state machine software module that control the actual actions to be done by the Hardware Engines. The actions order and parameters are stored in configuration files managed and edited by the user using the Process Configuration Interface module.

1.1.2. GUI Events loop – An events driven module responsible of collecting instructions from the user and displaying the application status and live measurements.

1.1.3. Hardware Parameters Interface – A user interface module enabling the user to edit the parameters defining any hardware prameters and save it into a textual file to be used by the Hardware Modules

1.1.4. Process Configuration Interface – a graphic interface tailored made to this specific application. Visualizing the process to be activated by the Scheduler and enabling the user to interactivly create the application measurement process. This configuration is saved into a file to be used later by the Process manager

1.1.5. Results engine and report Viewer – Every task carried out by the process manager should create an entry in the results file. These files can be viewed and analyzed later. The Report viewer can open the results files and display their content graphically.

1.1.6. Motors/Stage module – A software engine communicated by Queue, responsible of controlling the movement of the camera all along its movement trajectory as well as providing tilt, pan and zoom control

1.1.7. Image Acquisition module – A software engine communicated by Queue, connected to the camera. This module is responsible of collecting the image and activating the needed processing as requested by the Process Manager

1.2. Typical Hardware Module Structure

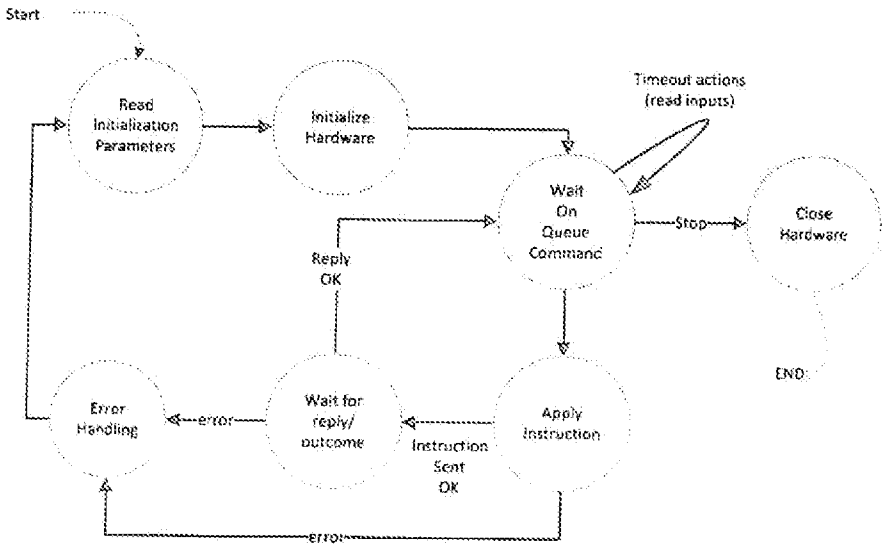


Figure 2: Typical Hardware Module State Machin

In the application ther are 2 Hardware Modules -- Motors/Stage Module and Image Acquisition Module. The Hardware Module is a LabVIEW software thread built in a state machine form, conforming with National Instruments LabVIEW best practice programming. This state machine is Queue managed (i.e. a LabVIEW queue is waiting for instructions from the process manager) and thus does not consumes CPU usage while in idle mode. Answers and measurements from this module are then sent back to the caller using notification. The initialization parameters of the module are read from the configuration files edited using the Hardware Parameters Interface.
In these modules we also implement a Demo or Offline mode. This enables using the software wile there is no hardware connected to the system and by that ease the debugging and integration phase.

1.3. Project Scheduler Engine Structure

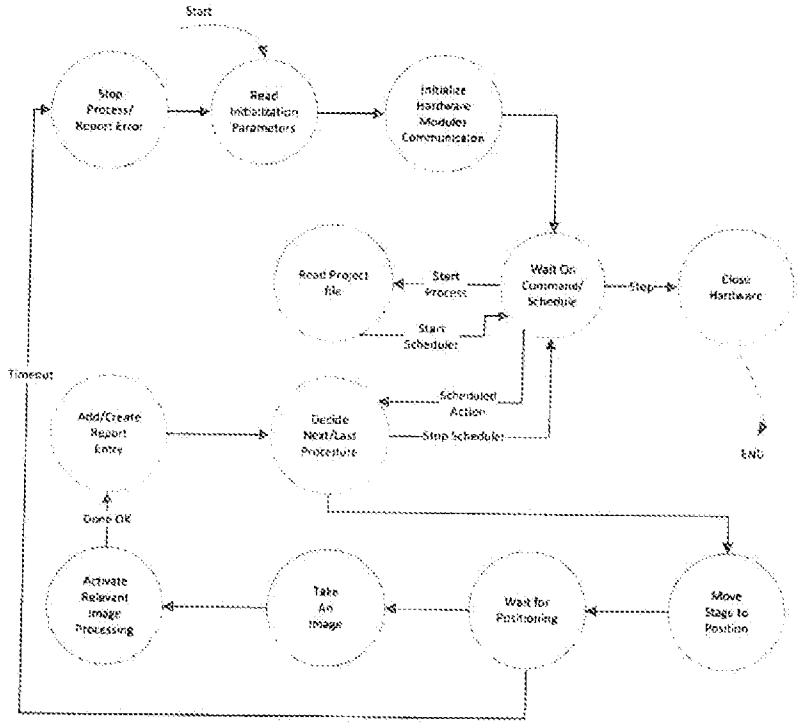


Figure 3: Process Engine Simplified State machine

As described in *Figure 3* the Project Scheduler Engine or the Process Engine is responsible of carrying out application task, weither it is a data acquisition application – gathering measurements while applying a certain hardware functionality or process manger – applying actions using the hardware to create a predefined complicated task.

This module is a labVIEW state machine thread with the following features:

1.3.1. The main Queue mechanism waits for commands and is responsible of "ticking" out a scheduled events to initiate the processes actions.

1.3.2. The scheduled process actions will move the stage to the desired position, take an image from the camera and perform the needed analyzing and actions

1.3.3. Once the last schaduled action has been carried out the scheduler will stop its "ticking" and wait for a command to start a new cycle of actions

2. The Grwponics Application Folders Tree Structure

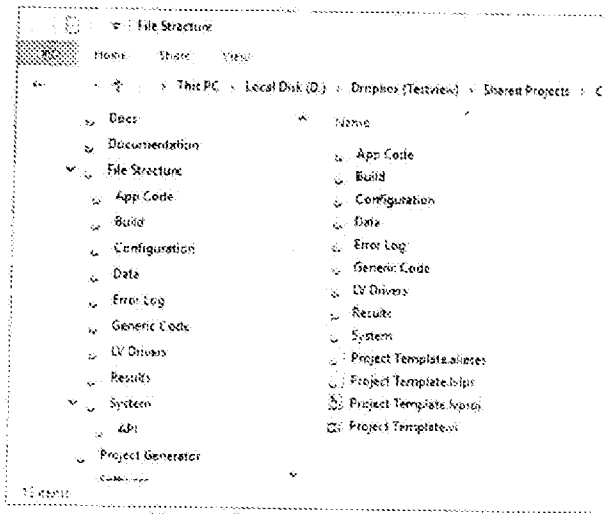


Figure 4: Grwponics folders structure

This application is conforming with Testview standard application file system structure as described belowin figure 4.

2.1. App Code – the actual labVIEW code of this specific application. This folder may be splited into several subfolders to enable better code management according to subVI functionality
2.2. Build – Storing the executable files generated by this project. To be copied in order to redistribute this application.
2.3. Configuration – A folder storing the Hardware configurations of the application
2.4. Data – generated by LabVIEW system – do not change
2.5. Error Log – Error logs generated by the application logger are stored here for later evaluation in case of application mulfuctions
2.6. Generic Code – Vis that are part of Testview infrastructure that are used trought our projets
2.7. LV Drivers – Hardware specific Vis. Seperated into sub folders to support each hardware device used in this application
2.8. Results – all application results are stored in here devided into subfolders according to the user conficuration
2.9. System – application initialization files

PCT Patent Application entitled: GREENHOUSE CONTROL SYSTEM

Docket: 5246/18

APPENDIX D

(34 Pages Total-including this page)

3.0 System Architecture

3.1 System Components:

A Growponics System consists of the following components:

- UNITS – RFS and / or NFT Systems
- NURSERY
- FERTILIZER CONTROL SYSTEM
- CLIMATE CONTROL SYSTEM
- REVERSE OSMOSIS SYSTEM

Each of these systems is discussed in greater detail in the sections following. A summary is provided here for each of these systems.

3.1.1 UNITS:

Units in a Growponics System are the Rotational Field Systems (RFS) and / or Nutrient Film Technique (NFT) modules that form the two types of Grow Beds in a Growponics System.

After preliminary preparation from seedlings in the Nursery, the developing plants are transferred to either the RFS flotation cells or to the NFT belt feed system.

Each Unit is monitored (pH, ORP, EC, Temperature and Water Level) and Control System setpoints are maintained by the Growponics Control system. Dosing of Nutrients, control of RFS cell relocation, pumping systems and numerous environmental controls are precisely maintained by the Control System.

3.1.2 NURSERY:

Seeds are planted in precisely locating germinating trays (17 by 26 Slots = 442 Seedlings per tray, know as a "442" at Growponics) for easy removal following maturation into seedlings for transfer to the RFS and NFT systems.

Seedling extraction is performed in a single easy process by a specially developed seedling extraction tool ("Plant Popper") developed and manufactured by Growponics.

A Misting system (a high-density matrix of fine sprays) above the seedling trays provides water via the Nursey pump for the plants whilst ideal growing conditions are maintained by the Climate Control system.

3.1.3 FERTILIZER CONTROL SYSTEM:

Nutrient rich water flows through the RFS and NFT systems to ensure optimal health and growth of the plants. Each RFS and NFT Unit is sampled (Process Variables – Electrical Conductivity, pH and ORP) in a sequential process (See Section XX – Sequence Flow Diagram and accompanying discussion). Once the current PV status is analysed for each

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Unit, the sequence then proceeds to dose the specific Unit with nutrients (Alfa and Beta additives) and the pH is maintained by addition of small levels of Acid or Base.

NFT channel nutrient flow is maintained by a system of electromagnet "hammers' that bump / jolt the flow lines to each NFT group of nutrient feed channels. This ensures good flow is maintained at all times.

Nutrient consistency is maintained by electrically powered Stirrers in the Alfa and Beta fertilizer additives.

3.1.4 CLIMATE CONTROL SYSTEM:

Climate in the Greenhouse is maintained by an Environmental Control system comprising several components.

The parameters that are the Inputs to the Climate Control system are the External Impacts of Outside Temperature, Relative Humidity / Moisture and Wind Speed and Direction, and Internal impacts of Inside Temperature, Humidity, Ultraviolet levels and Airflow in the Greenhouse atmosphere.

Outputs from the Control system control parameters such as Air throughput (extraction fans and Air Flaps to vent Air), Circulating Air across the respective Zones in the Greenhouse, Water flow to the Wet Pads, Cooling Towers providing chilled water and the UV level which is controlled by a UV limiting "curtain" that is Opened or Closed and extends across the entire Greenhouse facility (driven by a single induction motor centrally located and operated via a sophisticated system of pulleys and limit switches.

The Nursery Fogging system is also controlled by the Growponics Control System (see Nursery section above).

3.1.5 REVERSE OSMOSIS SYSTEM:

The Reverse Osmosis system extracts unwanted impurities from the Feed water and delivers pure, chemical and metals free water as make up water for the Greenhouse.

The Reverse Osmosis system in each Greenhouse or system of Greenhouses is controlled by a separate, standalone Control system with hard-wired Safety Interlocks to ensure guaranteed safety to personnel and to the RO System components which operate under very high pressure.

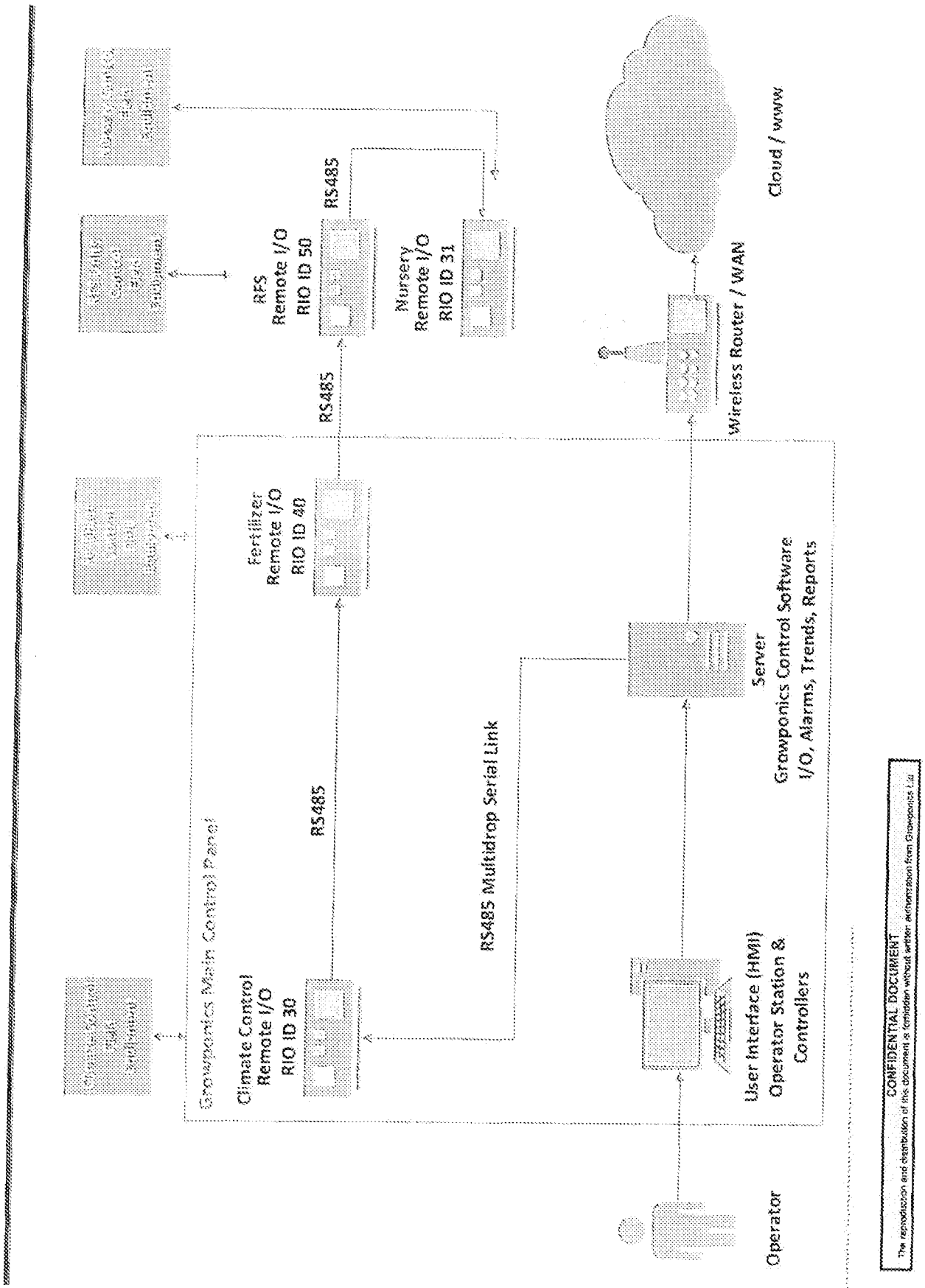
The RO system is monitored (EC) by the Growponics Control system however it has no direct control.

The RO system Sequence Start is via the RO system Local Control Panel.

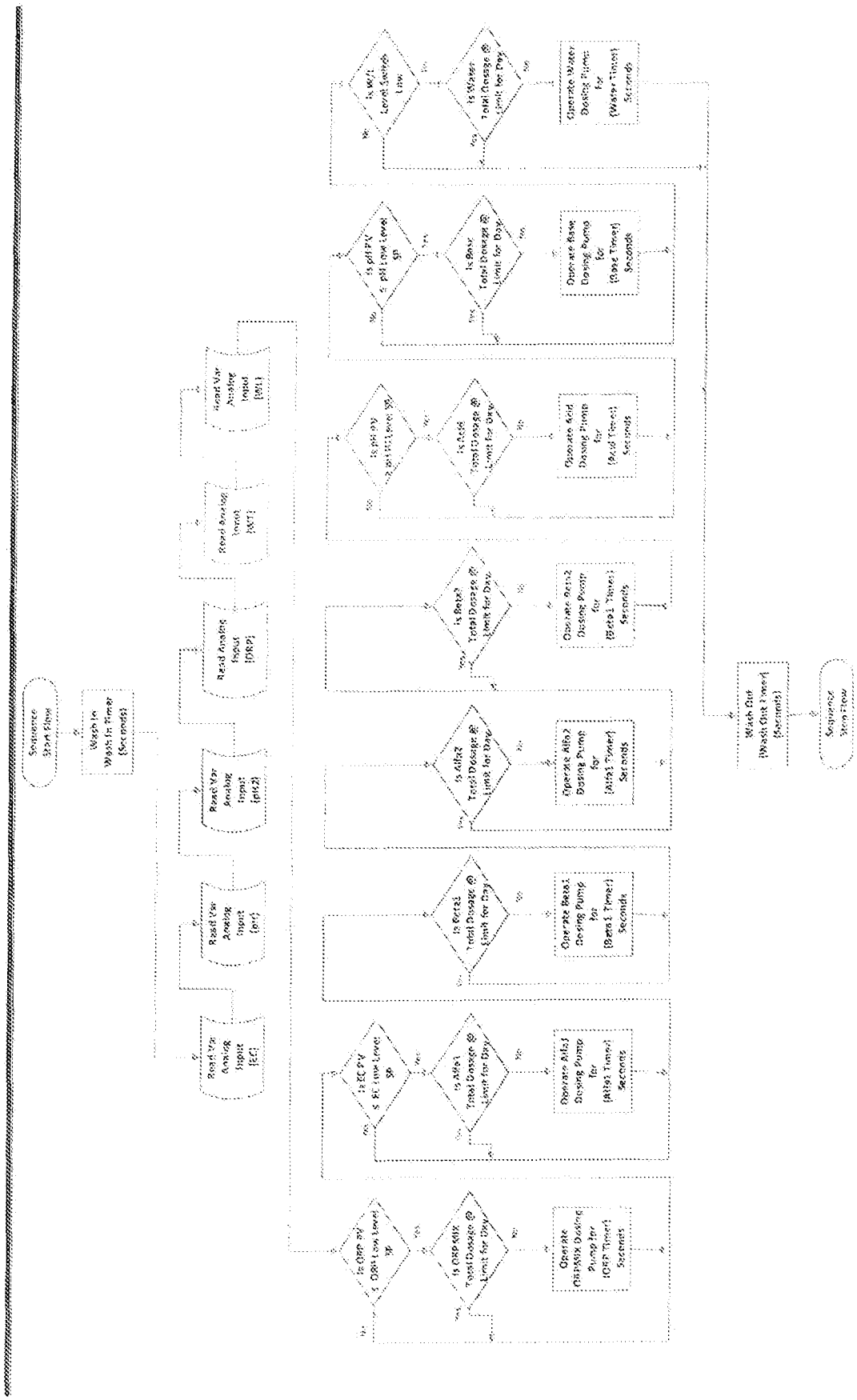
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3.2Growponics Control System – Block Diagram (Typical)

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Cloud / www
Wireless Router / WAN
RFS
Remote I/O
RIO ID 50
RS485
Nursery
Remote I/O
RIO ID 31
RS485
Fertilizer
Remote I/O
RIO ID 40
Growponics Main Control Panel
Climate Control
Remote I/O
RIO ID 30
RS485
RS485 Multidrop Serial Link
Server
Growponics Control Software
I/O, Alarms, Trends, Reports
User Interface (HMI)
Operator Station &
Controllers
Operator
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GrowPonics Ltd.
14 George Landwer St.
Kiryat-Bialik, 27033
Israel
T: +972 73 729-9950 ; F: +972 73 743-7917
info@growponics.co.uk ; www.growponics.co.uk
Doc. Title: Inspection procedure for greenhouse operation
Rev.:
Page: 15 Of 44
!!! User is the responsible to use updated copy of this procedure !!!
Figure 1 – Control System Block Diagram
**** ADD RO System to Block Diagram ****
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3.2Growponics Control Panel

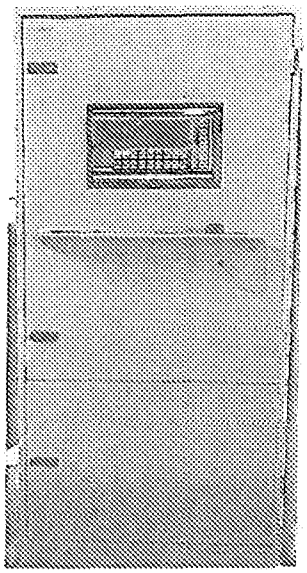


Figure 2 – Typical Growponics Main Control Panel

The Growponics Control System is comprised of a number of components as follows:

3.2.1 Main Control Panel

The Main Control Panel houses the Growponics Server hardware and software.
The Server integrates the functions of I/O Server, Alarm Server, Trend Server, Report Server and Fileserver.
The control software is a proprietary software package developed for each unique client system that contains all control algorithms, process sequence flows, data acquisition (remote I/O data reads & writes), communicating via serial (RS-485) communications to the RIO modules.
The Control Panel (as shown in this example) has 3 RIO (Remote I/O) modules housed in the Control Panel and a single RIO module located remotely in the Greenhouse.
The Human Machine Interface (HMI) is displayed on an LCD display in a window in the Control Panel. A keyboard and mouse are located beneath the HMI Screen. Operator Data entry (e.g. changing setpoints) is via the Control Panel HMI or via a VNC connected remote workstation that has access privilege to the control commands.

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3.2.2 Remote I/O (RIO Modules)

The RIO modules are connected to the Server as indicated via a multi-drop serial bus. Each RIO module has a unique device address (0 to 255) and has I/O to field instrumentation, pumps, valves, solenoids etc. Each RIO module has:

- 24 Opto-Isolated Digital Inputs
- 16 Relay Digital Outputs, and
- 6 Analog Inputs
- 3 Serial communications (RS-485) channels

3.2.3 Field Equipment

Field connected equipment consists of digital and analog inputs and digital outputs interfaced to instrumentation reading ORP, pH, EC, Level indication, Temperature and controlling dosing agents, pumps, valves, solenoids, fans, heaters, UV curtains, circulating fans, windows, wetpads, cooling towers, and chillers.

The above block diagram shows common plant area's being monitored and controlled:

- Fertilizer Control
- RFS X-Y Axis Control
- Climate Control
- Nursery Control

3.2.4 Remote Access

To LAN / WAN via local ethernet and wireless (LAN) or the Cloud via the local Router to the WWW / Internet.

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4.0 Screens & Tabs

4.1 Startup / Nutrition Page

The example screens shown following are typical of a Growponics Automation system.

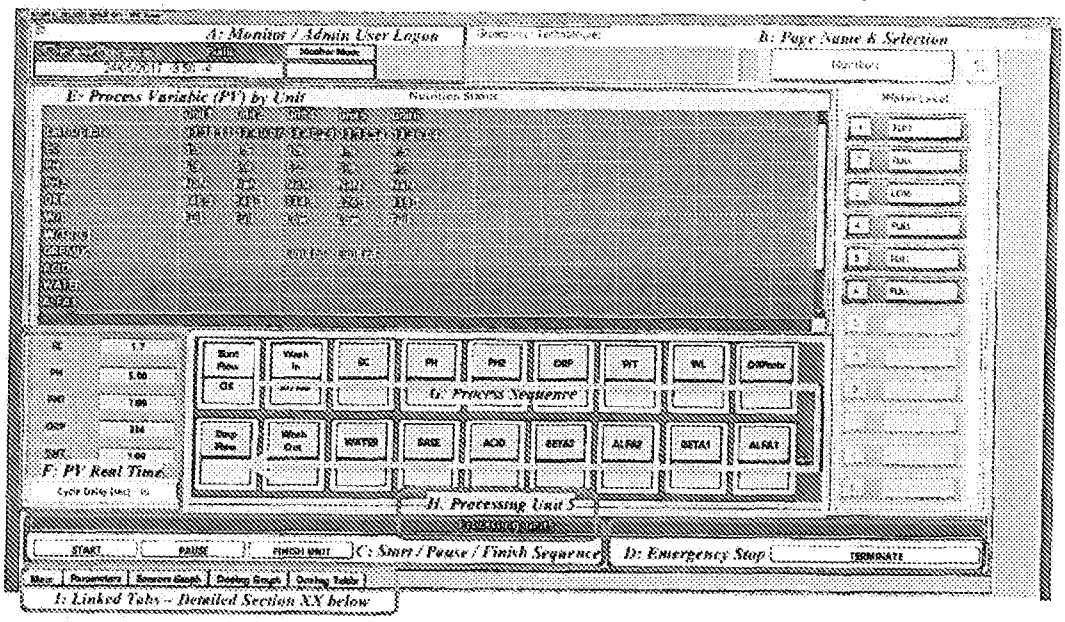


Figure 3 – Startup / Nutrition Screen

Figure (1) above shows the Main screen for the Growponics Automation system version 3.XX

This screen controls each Unit's Sequence Start and Stop cycle.

A Detailed Description follows for each of the highlighted boxes indicated in the Main Screen labelled A to H as follows:

4.1.1 A: Monitor / Farm Manager User Login – (Red box, top left)

To change from Monitor (View-Only access) to Farm Manager access in order to change process parameters (Setpoints, timers and other system parameters), enter the password by selecting the text entry box (grey) below "Monitor". Enter the password for Farm Manager access, if correctly entered, the "Monitor" background will change

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to green and indicate who is logged in. Setpoints and other parameters can now be changed. To return to "Monitor" mode, click on the Monitor / Farm Manager (green) box and the system will return to Monitor / View only access.

YY Check: Is "Save" required in above Login / Logout where changes are made?

4.1.2 B: Page Name & Selection (Yellow Box, top right)

The drop-down box indicates the current Page Name. Selecting the down-arrow provides a list of alternative page selections (Manual Mode / Nutrition / Climate / RFS / ERP)

4.1.3 C: Start / Pause / Finish Sequence

Start: To start the cycle, press the "Start" button and the system will scan the Remote I/O channel checking the units (the button will be green). The unit selected will then commence the process sequence.

Pause: If there is a need to pause the system during the process cycle, and then continue from the same point, press on the pause button (Note: this is not recommended).

Finish: To stop the system and there is no emergency condition, press on the Finish Unit button and the system will complete the current cycle and all processing will then Stop. The system will not move onto the next Enabled Unit.

4.1.4 D: Terminate (Emergency Stop)

Clicking on "Terminate" will immediately halt Fertilizer processing on All Units.
Note that it will not halt the Climate Control operation.

4.1.5 E: Process Variable (PV) by Unit

The Process Data window (mid screen) indicates the last state of each Process Variable at the completion of its last cycle by Unit #

Process Variables:

Last Update: This displays the time (HH:MM:SS format) of completion of processing the sequence for the Unit as shown.

EC: Displayed value is the Electrical Conductivity at completion of the last cycle.

pH: Displayed value is the pH at completion of the last cycle

ORP: Displayed value is the Oxygen Reduction Potential at completion of the last cycle in mV

W/L: Displayed value is the Water Level as a digital status as Full or Low

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W/T °C: Displayed value is the Water Temperature in each unit.

4.1.6 F: Process Variable (PV) in Real Time

This window (lower left) displays the Process Variable data for each of the parameters shown in Real Time (live data).

4.1.7 G: Process Sequence

The Process Sequence windows shows progress of an operating sequence for the Unit currently processing. The highlighted blue arrow shows the sequence commencing as follows:

Sequence Steps

Step 1 Sequence Start Flow Command
Step 2 Wash In Cycle (on timer parameter)
Step 3 Read Analog Inputs (EC, pH, ORP, WT) and Read Dig Input WL
Step 4 If required, add ORPMIX (on timer parameter)
Step 5 If required, add Nutrients Alfa1, followed by Beta1 (on timer parameter)
Step 6 If implemented and if required, add Nutrients Alfa2, followed by Beta2 (on timer parameter)
Step 7 If required, add Acid (pH Upper) (on timer parameter)
Step 8 If implemented and if required, add Base (pH Lower) (on timer parameter)
Step 9 If Water Level Low, Add Water until WT (Dif Input) at Full Level
Step 10 Wash Out Cycle (on timer parameter)
Step 11 Sequence Stop Flow Command

On completion and a preset time delay, the process will commence the sequence for the next Unit enabled for processing.

4.1.8 H: Process Unit # (RFS / NFT / VINE) currently in operation

The Unit # indicated is the Unit currently in sequence.

4.1.9 I: Linked Tabs – Detailed in Section 4.3 below

These Tabs are discussed in the following section.

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4.2 Sequence Flow Diagram

Insert New Sequence Diagram here in A3 Landscape

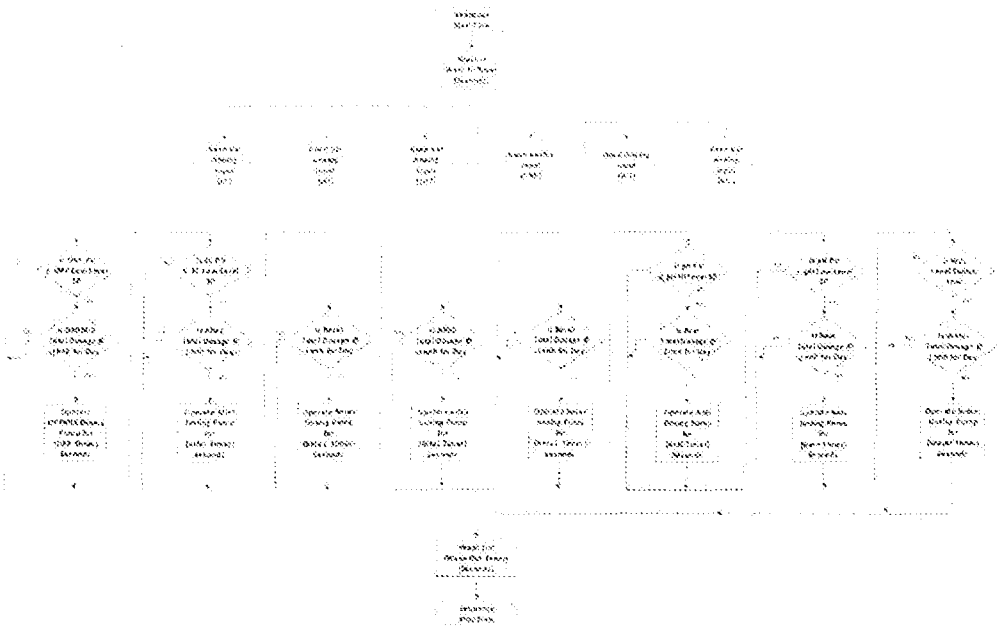


Figure 4 – Startup / Nutrition Screen

Note that where dosing agents Alfa2 and Beta 2 are in use, this action is implemented between the Alfa 1 / Beta 1 dosing actions and the Acid and Base dosage actions.

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4.3 Main Screen Tabs

4.3.1 Main Tab

The First Tab, the "Main" Screen Tab (4.1.9) will take the Operator back to the Main Screen described in Section 5.1 above.

4.3.2 Parameters Tab

Parameters: The Second Tab, when logged in as Farm Manager, permits data entry of Setpoints

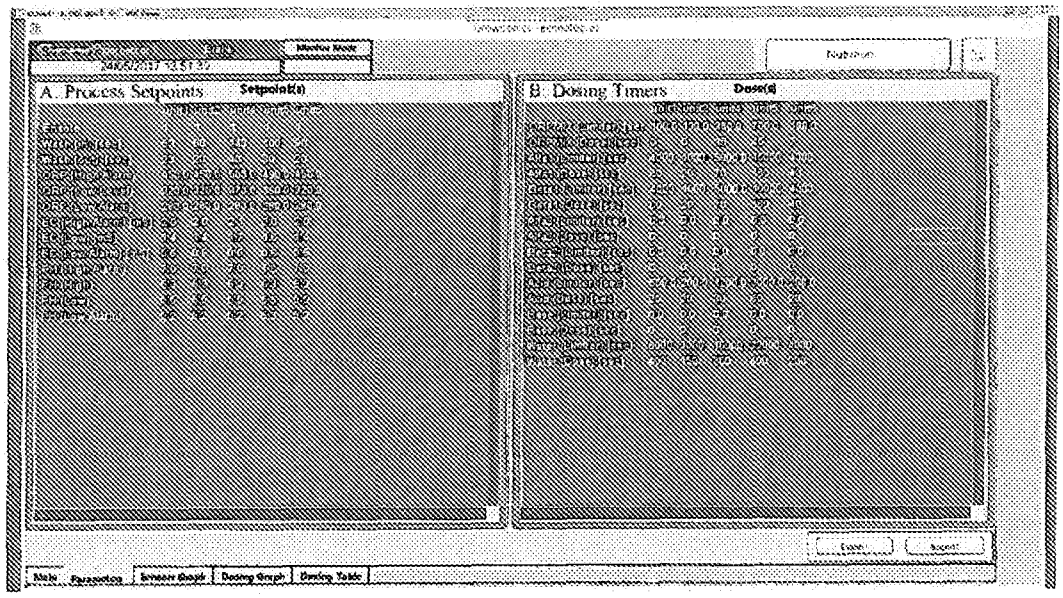


Figure 5 – Parameters Screen: Setpoint & Dosing

4.3.3 Process Setpoints Data Entry Table (A: Process Setpoints in Figure 3, Section 4.1)

In this Data Entry Table,when logged in as Engineer / Administrator, each Process Unit (RFS or NFT):

- Can be enabled for Operation (Process Sequence) – in the Enable row, (place mouse pointer over the row/column entry field) and enter a 1 to Enable the respective unit, or 0 if the unit is to bypass (disable) the

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process sequence. Click on the blue circular arrows (top right hand corner) and click on "Save" to Enable the Unit.

- Process Unit Setpoints, Timers and Alarms be adjusted by placing the mouse as above over the data entry field, entering the new value and also selecting "Save" by clicking on the blue circular arrows (top right-hand corner).

4.3.4 Process Setpoints Parameters:

The parameters are as follows: (Click on Save when date entry is completed)

- Enable: To Add a unit to the sequence, enter the number 1
  To Remove a unit from the sequence, enter the number 0
- Wash (in) (sec): Enter the time in seconds required for the unit wash when the process starts in each unit.
- Wash (out) (sec): Enter the time in seconds required for the unit wash when the process finishes in each unit
- ORP (High Alarm): Enter the ORP alarm set point High Limit at which the system will alert the Operator
- ORP (Low Level): Enter the ORP level set point Low Level below which the system will inject ORPMIX solution
- ORP (Low Alarm): Enter the ORP alarm set point Low Limit at which the system will alert the Operator
- EC (High Alarm) (mS): Enter the EC alarm set point High Limit at which the system will alert the Operator
- EC (Low) (mS): Enter the EC conductivity set point Low Level below which the system will inject solution (the actual EC the system is required to maintain).
- EC (Low Alarm) (mS): Enter the EC conductivity set point Low Limit below which the system will alert the Operator and *will not inject* solution.
- pH (High Alarm): Enter the pH alarm set point High Limit above which the system will alert the Operator and *will not* inject solution.
- pH (High): Enter the pH set point High Level above which the system *will inject* Acid solution (the actual pH the system is required to maintain).
- pH (Low): (Where implemented – Optional)
  Enter the pH set point Low Level below which the system *will inject* Base / Alkaline solution.
- pH (Low Alarm): Enter the pH alarm set point Low Limit below which the system will alert the Operator and *will not inject* solution.

4.3.5 Dosing Timers Data Entry Tab (8: Dosing Timers in Figure 3)

In this Data Entry Table,when logged in as Engineer / Administrator, each Process Units :

The Dosing Timer Setpoints can be adjusted by placing the mouse as above over the data entry field in the Main → Parameters screen by entering the new value and also selecting "Save" by clicking on the blue circular arrows (top right hand corner).

- Alfa 1 (Limiter) (sec) Enter the limit in seconds that nutrient Alfa1 will be injected in a 1 day period.
- Alfa 1 (Dose) (sec) Enter the time in seconds that nutrient Alfa1 will be injected each cycle when required.

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- Beta 1 (Limiter) (sec) Enter the limit in seconds that nutrient Beta1 will be injected in a 1 day period.
- Beta 1 (Dose) (sec) Enter the time in seconds that nutrient Beta1 will be injected each cycle when required.
- Alfa 2 (Limiter) (sec) Enter the limit in seconds that nutrient Alfa2 will be injected in a 1 day period.
- Alfa 2 (Dose) (sec) Enter the time in seconds that nutrient Alfa2 will be injected each cycle when required.
- Beta 2 (Limiter) (sec) Enter the limit in seconds that nutrient Beta2 will be injected in a 1 day period.
- Beta 2 (Dose) (sec) Enter the time in seconds that nutrient Beta2 will be injected each cycle when required.
- Acid (Limiter) (sec) Enter the limit in seconds that Acid will be injected in a 1 day period.
- Acid (Dose) (sec) Enter the time in seconds that Acid will be injected each cycle when required.
- Base (Limiter) (sec) Enter the limit in seconds that Base will be injected in a 1 day period.
- Base (Dose) (sec) Enter the time in seconds that Base will be injected each cycle when required.
- Water (Limiter) (sec) Enter the limit in seconds that Water will be injected in a 1 day period.
- Water (Dose) (sec) Enter the time in seconds that Water will be injected each cycle when required.

4.4 Manual Screen Tabs

Insert detail of these screens – to be added....

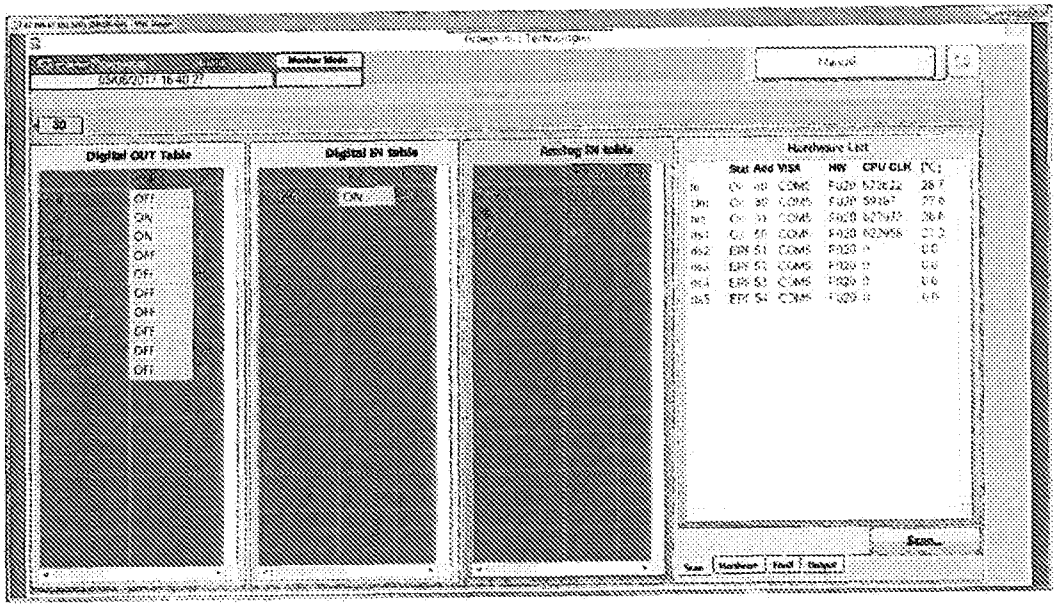


Figure 6 – Manual Screen (Scan Tab)

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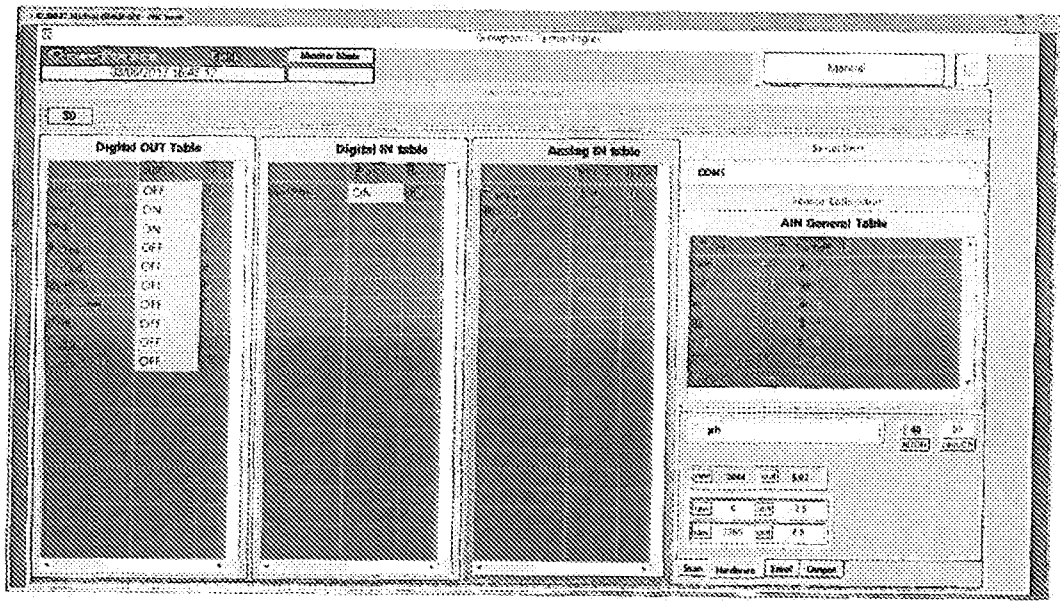


Figure 8 – Manual Screen (Hardware Tab)

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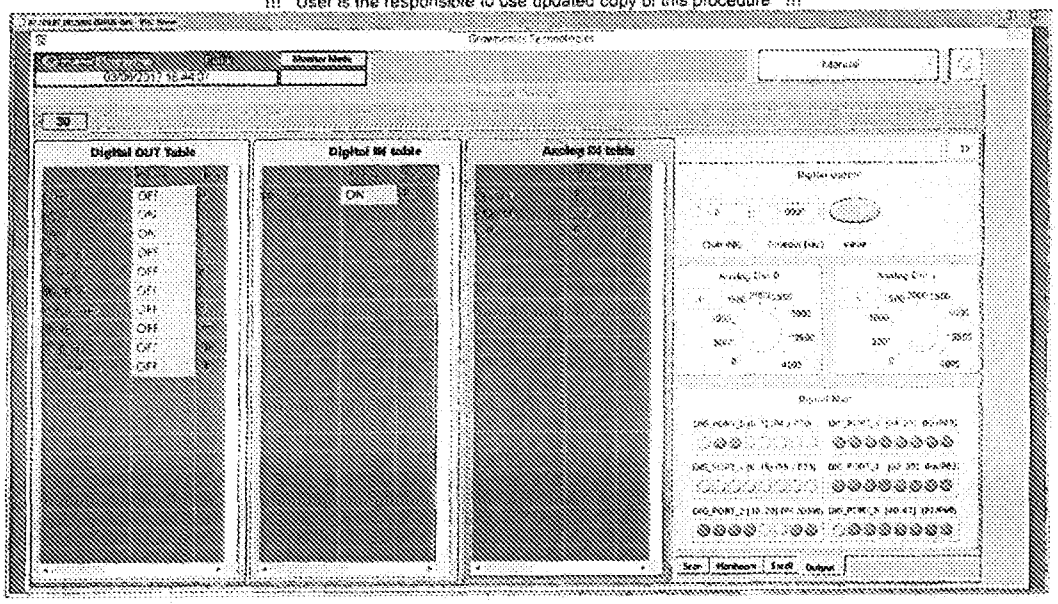
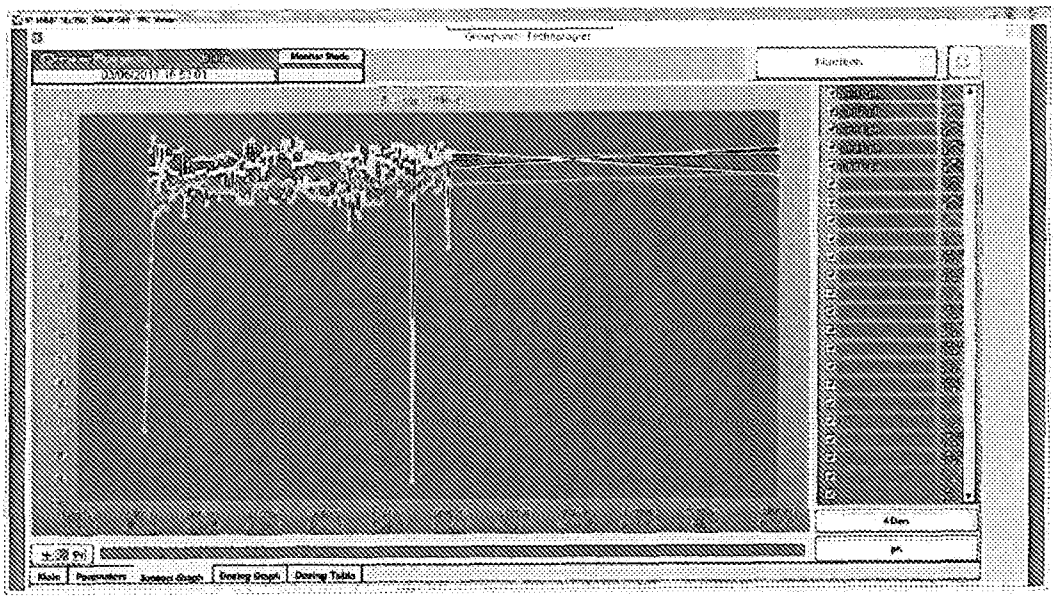


Figure 9 – Manual Screen (Output Tab)

TRENDING Parameters: Content to be added



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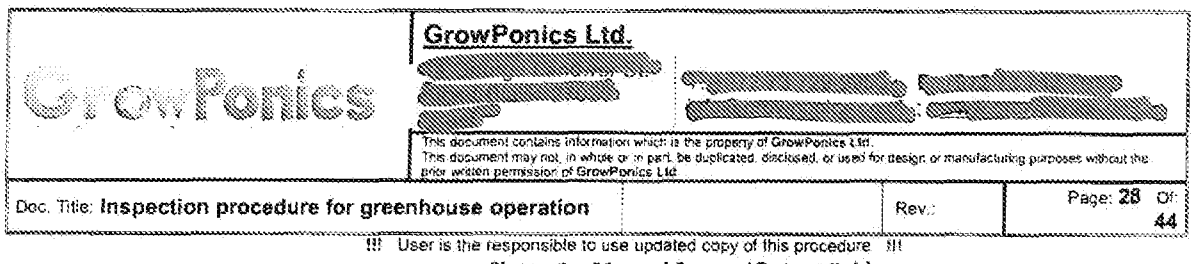
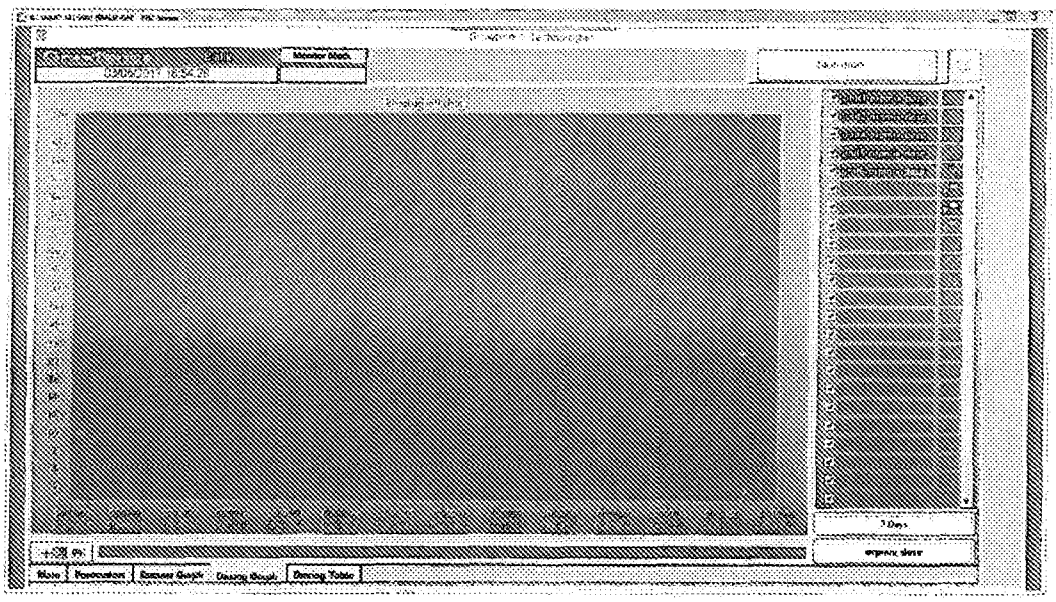


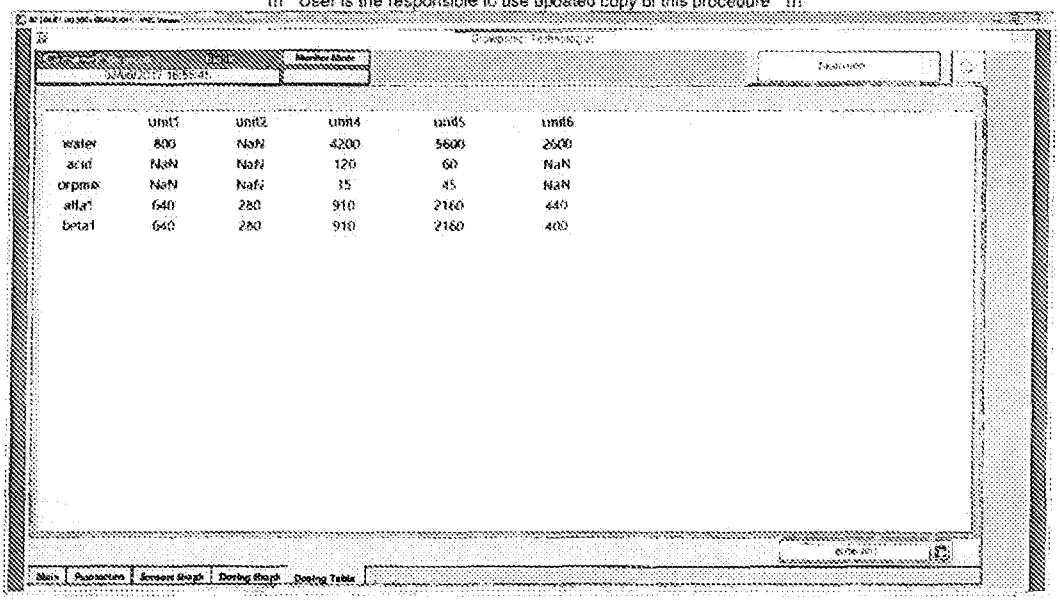
Figure 9 – Manual Screen (Output Tab)

Content to be added



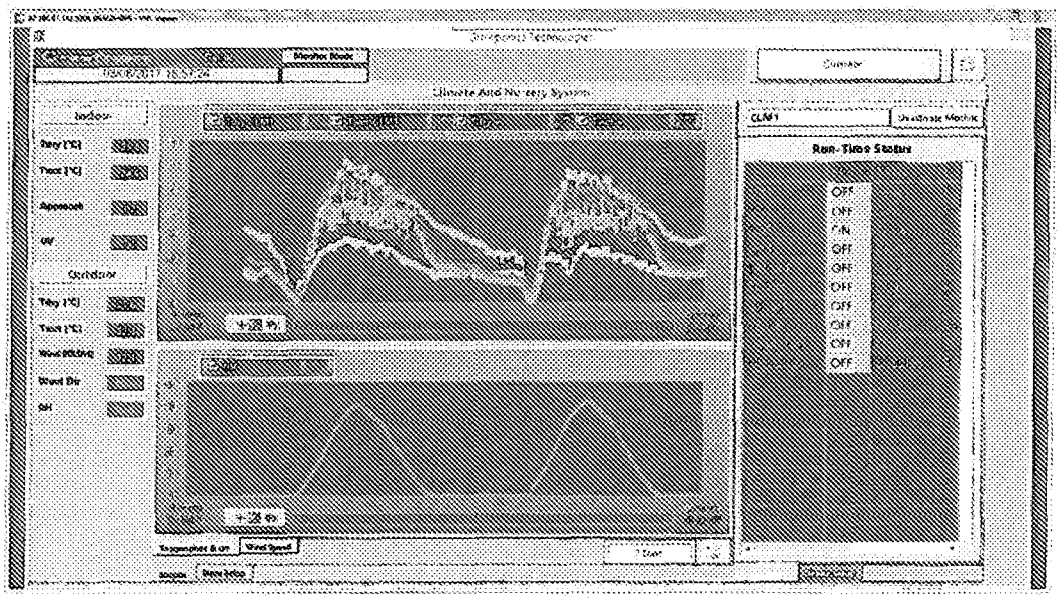
Content to be added

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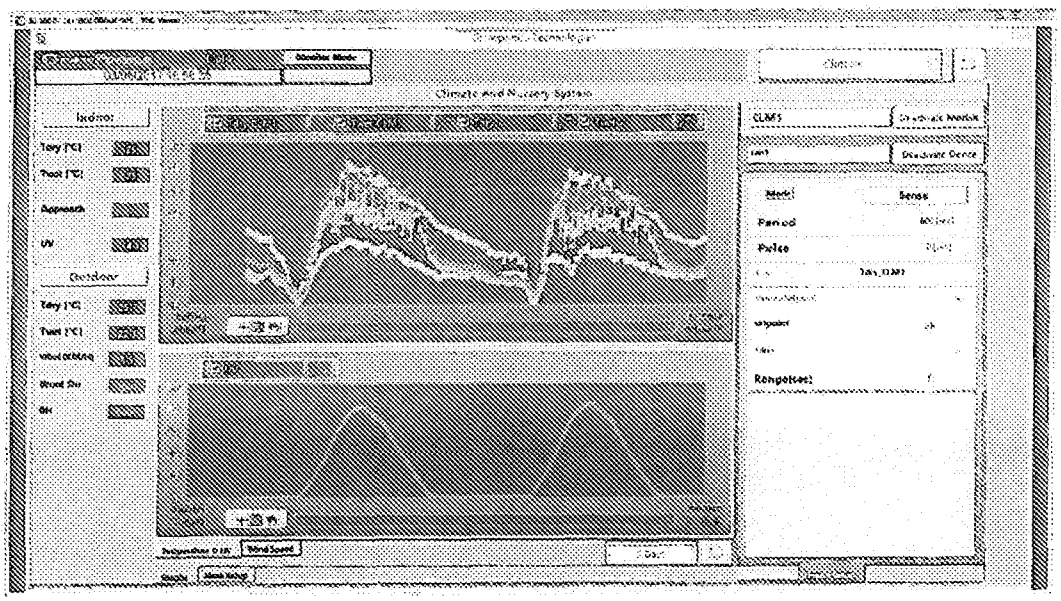


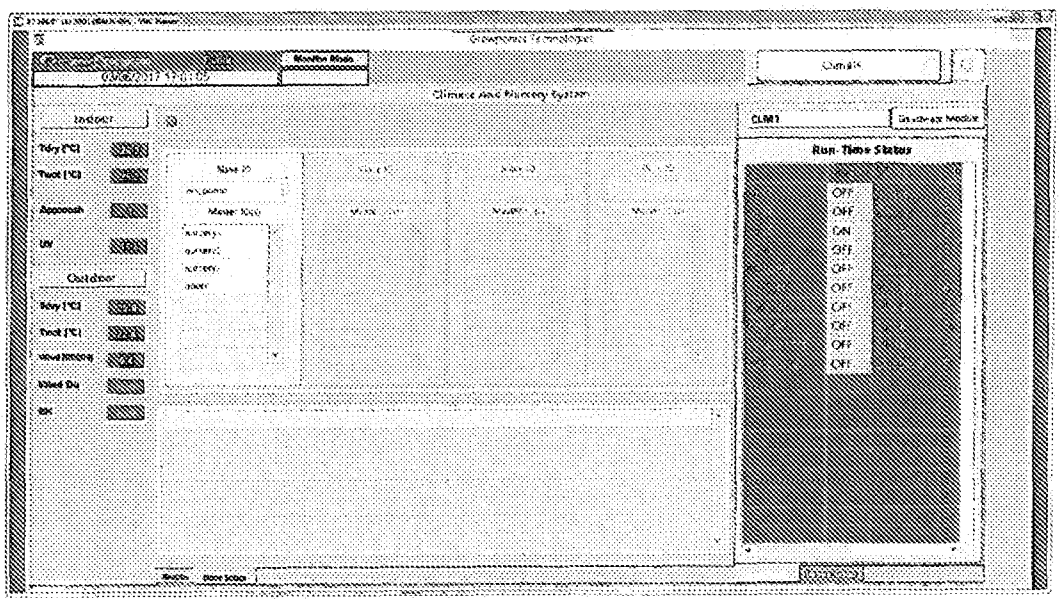
	unit1	unit2	unit4	unit5	unit6
water	800	NaN	4200	5600	2600
acid	NaN	NaN	120	60	NaN
orpmax	NaN	NaN	35	45	NaN
alfa1	640	280	910	2160	440
beta1	640	280	910	2160	400

Climate & Nursery



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6.0 Trends

6.1 System Configuration

Still Under Development

7.0 Alarms & Events

7.1 Reports

8.5 ERP

Enterprise resource planning (ERP) is the integrated management of core business processes, often in real-time and mediated by software and technology. Growponics implementation of ERP includes:

- Remote systems management
- Control of Setpoints to ensure ideal growth conditions
- Product planning and Sales advice
- marketing and sales expertise
- Materials management
- Inventory management
- Shipping & Product Delivery Advice
- Where appropriate, assistance with Finance

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8.6 Operational Sequence – Detailed Description

8.6.1 Reagent Mixing

Stage 1 - ORPMIX Addition.

The ORPMIX is an equal mix of HCL and NACL in solution pumped via solenoid pumps from each liquids reservoir. The mixture is combined via a 2-in, 1-out combiner and pumped directly into the delivery manifold.

8.6.2 Stage 2 - Nutrients Addition (Alfa1,2 Beta1,2)

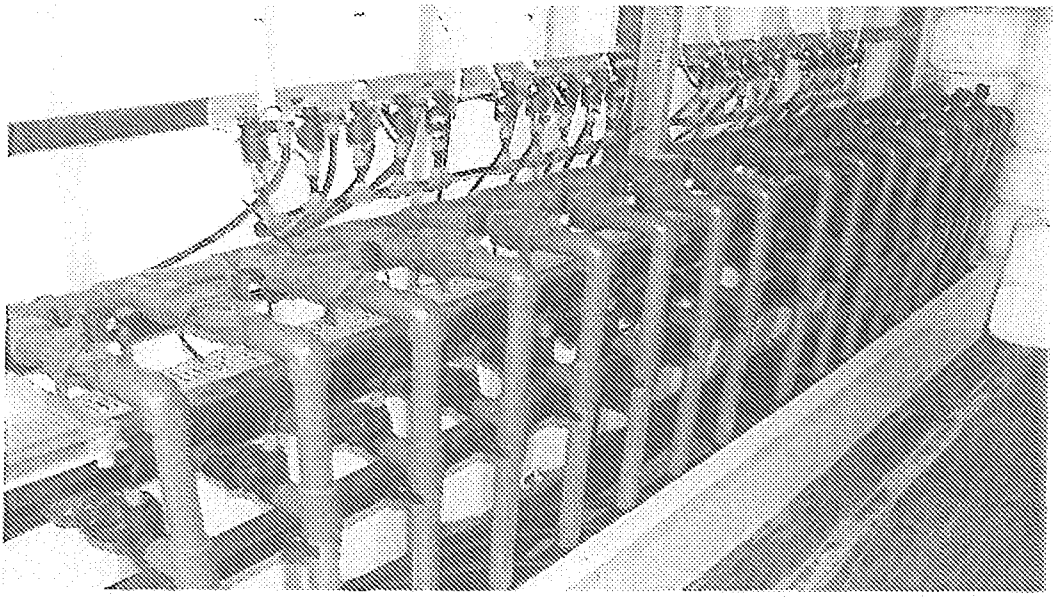
The nutrients are pumped into the delivery manifold via individual solenoid pumps. The Alfa-1 is delivered into the line first, followed by the Beta-1 nutrient. These are delivered separately due to a chemical reaction that would occur if both nutrients were delivered simultaneously.

Stage 3 - Acid / Base Addition.

Note: As water – both Town Water and Ground Water, are generally alkaline, there is often no requirement for adding base chemicals, only acid. However, where required, base chemicals can be included in the Control system for dosing.

Acid:

Base:

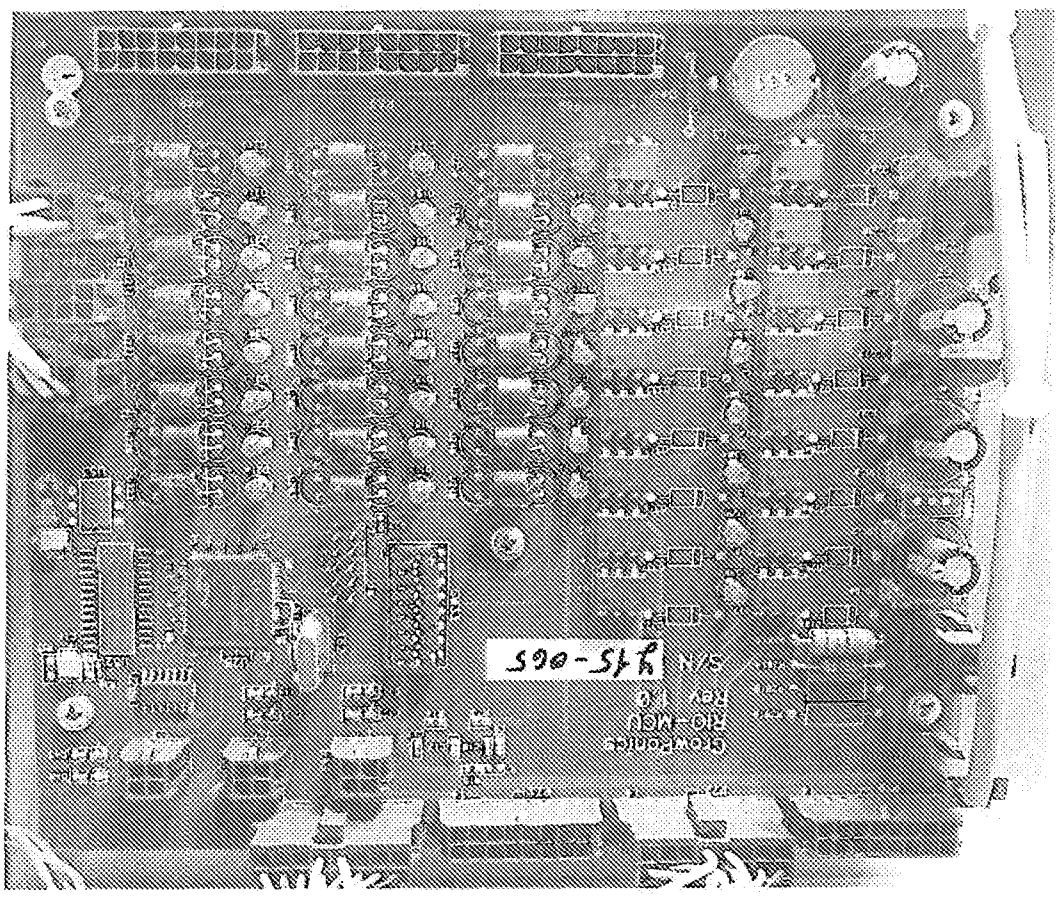


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3.4 Hardware

3.4.1 Central Processing Unit – PC Hardware

3.4.2 Remote I/O RIO-MCU



Each Remote I/O Module has:

- 24 Digital Inputs, 24Vdc
- 16 Digital (Relay / Dry Contact) Outputs
- 6 Analog Inputs, 0 / 4 – 20mA
- 3 Serial Data Connections, RS-485

3.4.2.1 Module ID – Setting DIP Switches

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The DIP Switch selects the Device Address is split into 2 by 4 bit Hex Addresses for a total of 256 devices. Thus FF or 1111 1111 represents address 255. Example: An address of 41 will be represented by 0100 0001

4.0 RS-485 Communications

Communication between the Computer and the Remote IO Modules is via RS-485 multidrop serial link. A USB to RS-232 Serial Converter connects to a USB Port on the computer and the RS-232 side of the converter is connected to a Moxa port-powered RS-422 / RS-485 converter. The converter operates in the 4-wire full-duplex RS-485 mode. The differential balanced line provides for data links up to 1200m. This distance can be further extended using repeaters.

RS-485 allows up to 32 devices to be connected to the serial bus and well beyond this number with the use of Bus repeaters and Bus Splitters. The Bus Master (the PC) does not have an address. The Slave (RIO) modules have addresses from 0 to 255.

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Remote I/O (RIO) Module *Examples* – Input & Output Assignments for a 3 RFS / 2 NFT System

Climate Control Example:

RIO Module Address: 30 CLIMATE CONTROL

Digital Inputs

I/P #	Dig Input	Status	Port
1	220Vac	On / Off	40
2	Spare	On / Off	
3	Spare	On / Off	
4	Spare	On / Off	
5	Spare	On / Off	
6	Spare	On / Off	
7	Spare	On / Off	
8	Spare	On / Off	
9	Spare	On / Off	
10	Spare	On / Off	
11	Spare	On / Off	
12	Spare	On / Off	
13	Spare	On / Off	
14	Spare	On / Off	
15	Spare	On / Off	
16	Spare	On / Off	
17	Spare	On / Off	
18	Spare	On / Off	
19	Spare	On / Off	
20	Spare	On / Off	
21	Spare	On / Off	
22	Spare	On / Off	
23	Spare	On / Off	
24	Spare	On / Off	

Digital Outputs

Rly O/P #	Output	On / Off	Index
1	Fan 1	On / Off	0
2	Fan 2	On / Off	1
3	Fan 3	On / Off	2
4	UV Curtain	On / Off	3
5	TH Curtain	On / Off	4
6	Wet Pad	On / Off	5
7	Spare	On / Off	6
8	Spare	On / Off	7
9	NFT Pump	On / Off	8
10	Spare	On / Off	9
11	Spare	On / Off	10
12	Spare	On / Off	11
13	Spare	On / Off	12
14	Fan 4	On / Off	13
15	Fogger	On / Off	14
16	Circulators	On / Off	15

Analog Inputs

Ana I/P #	Ana Input	Port
1	Tdry_x	0
2	Twet_x	1
3	UV	2
4	Spare	3
5	Spare	4
6	Spare	5
7	Not Implemented	
8	Not Implemented	
9	RIO_CPU_Temp	8

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Fertilizer Example:

RIO Module Address: 40 — FERTILIZER

Digital Inputs

I/P #	Dig Input Unit4_W	Status	Port
1	L	On / Off	39
2	Spare	On / Off	
3	Spare	On / Off	
4	Spare	On / Off	
5	Spare	On / Off	
6	Spare	On / Off	
7	Spare	On / Off	
8	Spare	On / Off	
9	Spare	On / Off	
10	Spare	On / Off	
11	Spare	On / Off	
12	Spare	On / Off	
13	Spare	On / Off	
14	Spare	On / Off	
15	Spare	On / Off	
16	Spare	On / Off	
17	Spare	On / Off	
18	Spare	On / Off	
19	Spare	On / Off	
20	Spare	On / Off	
21	Spare	On / Off	
22	Spare	On / Off	
23	Spare	On / Off	
24	Spare	On / Off	

Digital Outputs

Rly O/P #	Output	On / Off	Index
1	Spare	On / Off	0
2	Spare	On / Off	1
3	Spare	On / Off	2
4	Spare	On / Off	3
5	Spare	On / Off	4
6	Spare	On / Off	5
7	Spare	On / Off	6
8	Spare	On / Off	7
9	Spare	On / Off	8
10	ORPMIX	On / Off	9
11	BETA1	On / Off	10
12	BETA2	On / Off	11
13	ACID	On / Off	12
14	BASE	On / Off	13
15	WATER	On / Off	14
16	ALFA2	On / Off	15

Analog Inputs

Ana I/P #	Ana Input	Port
1	pH2	0
2	Spare	1
3	pH	2
4	EC	3
5	WT	4
6	ORP	5
7	Not Implemented	6
8	Not Implemented	7
9	RIO_CPU_Temp	8

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22	Spare	On / Off	
23	Spare	On / Off	
24	Spare	On / Off	

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Rotating Field System:

RIO Module Address: 50 ROTATING FIELD SYSTEM RFS

Digital Inputs

I/P #	Dig Input	Status	Port
1	RFS1_SW	On / Off	24
2	RFS2_SW	On / Off	25
3	RFS3_SW	On / Off	26
4	RFS4_SW	On / Off	27
5	RFS5_SW	On / Off	28
6	RFS6_HMR_SW	On / Off	29
7	RFS7_SW	On / Off	30
8	RFS8_SW	On / Off	31
9	Spare	On / Off	32
10	Spare	On / Off	33
11	UNIT3_WL	On / Off	34
12	Spare	On / Off	35
13	UNIT6_WL	On / Off	36
14	UNIT2_WL	On / Off	37
15	UNIT1_WL	On / Off	38
16	UNIT5_WL	On / Off	39
17	Spare	On / Off	
18	Spare	On / Off	
19	Spare	On / Off	
20	Spare	On / Off	
21	Spare	On / Off	
22	Spare	On / Off	
23	Spare	On / Off	
24	Spare	On / Off	

Digital Outputs

Rly O/P #	Output	On / Off	Index
1	Spare	On / Off	0
2	Spare	On / Off	1
3	Spare	On / Off	2
4	Spare	On / Off	3
5	Spare	On / Off	4
6	Spare	On / Off	5
7	Spare	On / Off	6
8	Spare	On / Off	7
9	Spare	On / Off	8
10	RFS5_Y	On / Off	9
11	RFS6_X	On / Off	10
12	RFS6_Y	On / Off	11
13	RFS7_Y	On / Off	12
14	RFS7_X	On / Off	13
15	RFS8_X	On / Off	14
16	RFS8_Y	On / Off	15

Analog Inputs

Ana I/P #	Ana Input	Port
1	Spare	0
2	Spare	1
3	Spare	2
4	Spare	3
5	Tdry_CLM1	4
6	Twet_CLM1	5
7	Not Implemented	6
8	Not Implemented	7
9	RIO_CPU_Temp	8

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EXAMPLE CLIMATE & NURSERY SYSTEM – Module Devices & Modes

Module	Device	Mode1	Mode2	Mode3	Mode4	Mode5	Mode6	Period(Sec)	Pulse(Sec)	STATUS
CLM1	FAN1	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	600	0	OFF
CLM1	FAN2	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	500	0	OFF
CLM1	FAN3	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	10	0	ON
CLM1	FAN4	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	60	0	ON
CLM1	WETPAD	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	2	0	OFF
CLM1	THCurt	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	OFF
CLM1	UVCurt	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	20	0	ON
CLM1	FOGGER	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	20	0	OFF
CLM1	CIRCULATORS	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	60	0	OFF
CLM1	NFT_PUMP	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	OFF

Device	Device	Mode1	Mode2	Mode3	Mode4	Mode5	Mode6	Period(Sec)	Pulse(Sec)	STATUS
NRS	NURSERY1	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	OFF
NRS	NURSERY2	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	OFF
NRS	NURSERY3	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	OFF
NRS	NURSERY4	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	OFF
NRS	TOWER (Cooling)	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	ON
NRS	NRS_PUMP	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	ON
NRS	GARDEN	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	OFF
NRS	FRESH_WATER	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	ON
NRS	STIRRER	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	5	0	ON

Device	Device	Mode1	Mode2	Mode3	Mode4	Mode5	Mode6	Period(Sec)	Pulse(Sec)	STATUS
ALARMS	Tdry_CLM	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	OFF
ALARMS	220Vac	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	OFF
ALARMS	OSM_LOW_LEVEL	Disabled	OFF	ON	SENSE	CLOCK	EMAIL	----	----	ON

Note:

SENSE is "Sensor" Mode - See Set of Sensors that this Mode can operate based on which Sensor (there are many)

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Definition of Terms

Acronym	Description
A/L	Air Lift
Ch	Chiller
CF	Conductivity Factor
CT	Cooling Tower
CTF	Cooling Tower Fan
CTP	Cooling Tower Pump
CRC	CRC Pump
EC	Electrical Conductivity
FRT (B)	Fertilizer Dosing System
FRT (A)	Floating Raft Technology
NFT	Nutrient Film Technique
pH	Potential of Hydrogen
RWM	Roof Windows Monitor
RFS	Rotating Field System
TD	Temperature Dry (Outside)
TW	Temperature Wet (Inside)
ThSM	Thermal Screen Motor
HH	To Be Advised
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
U	Unit (RFS/NFT)
UP	Unit Pump
WF	Wall Fan
WL	Water Level
WT	Water Temperature
WP	Wet Pad

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Monitored Parameters

Parameter	Description	Range
EC	Electrical Conductivity	µS/cm
pH	Acidity / Alkalinity	0 - 14
pH2	Acidity / Alkalinity	0 - 14
ORP	Oxygen Reduction Potential	milliVolts
W/T	Temperature	deg C

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Example Unit Parameters & Alarms

Parameter	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	SI Unit
Wash In Timer	80	80	OOS	140	100	90	Seconds
EC	1.4	1.5	OOS	1.8	1.7	1.5	µS/cm
pH	6	6	OOS	6	6	6	0 - 14 (-log([H+])
pH2	6	6	OOS	6	6	6	0 - 14 (-log([H+])
ORP	345	345	OOS	345	345	345	MilliVolts
WT	23	23	OOS	23	23	23	deg C
WL	OK	OK	OOS	OK	OK	OK	OK / Not OK
Alfa1	80	20	OOS	70	180	40	Seconds
Beta1	80	20	OOS	70	180	40	Seconds
Alfa2	80	20	OOS	70	180	40	Seconds
Beta2	80	20	OOS	70	180	40	Seconds
Acid	20	20	OOS	30	60	20	Seconds
Base	20	20	OOS	30	60	20	Seconds
Water	400	150	OOS	0	400	200	Seconds
Wash Out	20	20	OOS	40	30	20	Seconds

Alarms	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	SI Unit
ORP Hi	450.00	450.00	OOS	500.00	490.00	450.00	MilliVolts
ORP Lo	320.00	320.00	OOS	370.00	360.00	320.00	MilliVolts
ORP Lo Lo	280.00	280.00	OOS	280.00	280.00	280.00	MilliVolts
EC Hi	2.00	2.00	OOS	2.10	2.00	2.00	µS/cm
EC Lo	1.40	1.40	OOS	1.70	1.60	1.40	µS/cm
EC Lo Lo	0.60	0.60	OOS	0.60	0.60	0.60	µS/cm
pH Hi Hi	7.00	7.00	OOS	7.00	7.00	7.00	0 - 14 (-log([H+])
pH Hi Hi	6.30	6.30	OOS	6.30	6.30	6.30	0 - 14 (-log([H+])
pH Lo	5.20	5.20	OOS	5.20	5.20	5.20	0 - 14 (-log([H+])
pH Lo Lo	5.50	5.50	OOS	5.50	5.50	5.50	0 - 14 (-log([H+])

OOS Unit Out of Service

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Common Soil Nutrients:

Periodic Table	Element
N	Nitrogen
P	Phosphorous
K	Potassium
Ca	Calcium
Mg	Magnesium
S	Sulphur
Na	Sodium
Cl	Chlorine
Fe	Iron
Mn	Manganese
Zn	Zinc
Cu	Copper
Mo	Molybdenum
B	Boron

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CLAIMS:

1. A method for data collection comprising:

providing a robot for moving along a controlled path, the robot including at least one sensor;

moving the robot to a first location for obtaining first data associated with the first location, and then to a second location; and,

moving the robot back to the first location for obtaining second data, and confirming that the robot is at the first location by:

analyzing presently sensed second data, and comparing the presently sensed second data against reference data for correspondence between the second data and the reference data.

2. The method of claim 1, additionally comprising, obtaining the second data and analyzing the second data against reference data for correspondence between the second data and the reference data.

3. The method of claim 2, wherein the reference data includes the first data.

4. The method of claim 2, wherein the correspondence between the data is based on reference points.

5. The method of claim 4, wherein the data includes one or more of: images, light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, and, motion detection.

6. The method of claim 4, wherein the correspondence is between one or more reference points in the second data and the reference data.

7. The method of claim 6, wherein the reference points include portions of second data and the reference data.

8. The method of claim 1, wherein the at least one sensor includes one or more of: a camera, and detectors for at least one of light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, and, motion detection.

9. The method of claim 1, wherein the controlled path includes at least one of a track or a rail.

10. The method of claim 1, wherein the robot is moved by signals from a controller remote from the robot.

11. The method of claim 1, wherein the first location is a preset, and the preset includes a position of the robot in space.

12. The method of claim 11, wherein the at least one sensor includes a camera for capturing images, and the preset location includes at least pan, tilt and zoom (PTZ) position of the camera.

13. A system for data collection comprising:

a robot for moving along a controlled path, the robot including at least one sensor; and,

a processor, the processor programmed for:

moving the robot to a first location for obtaining first data associated with the first location, and then to a second location; and,

moving the robot back to the first location for obtaining second data, and confirming that the robot is at the first location by:

analyzing presently sensed second data, and comparing the presently sensed second data against reference data for correspondence between the second data and the reference data.

14. The system of claim 13, wherein the at least one sensor includes one or more of: a camera, and detectors for at least one of light, temperature, pressure, humidity, air, air quality, smoke, pollution, thermal, infrared (IR) light and energy, sound, ultraviolet (UV) light and energy, nutrients, and, motion detection.

15. The system of claim 13, wherein the controlled path includes at least one of a track or a rail.

16. The system of clam 13, wherein the robot is moved by signals from a controller remote from the robot.

17. The system of claim 13, wherein the first location is a preset, and the preset includes a position of the robot in space.

18. The system of claim 17, wherein the at least one sensor includes a camera for capturing images, and the preset location includes at least pan, tilt and zoom (PTZ) position of the camera.

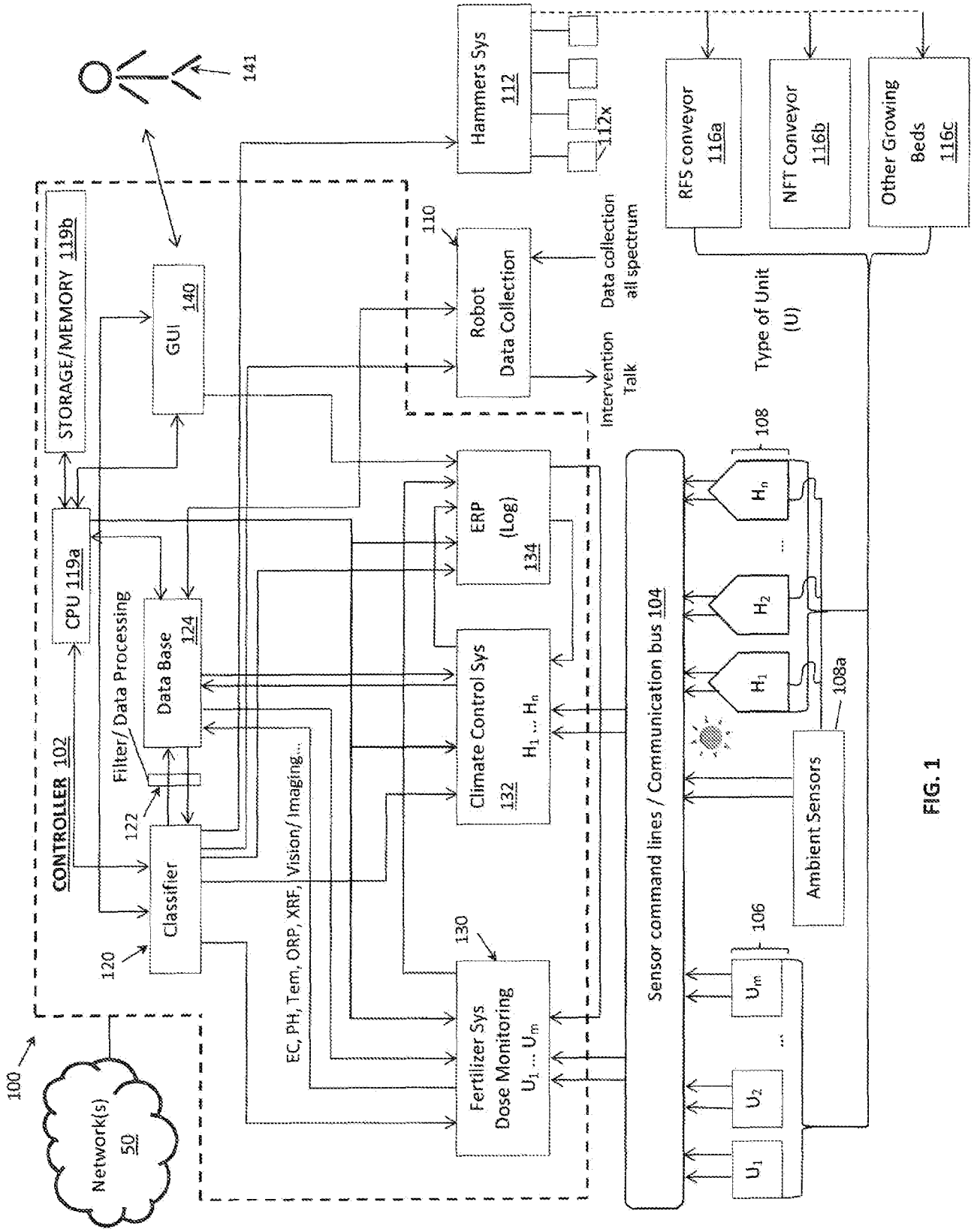

100
Network(s) 50
CONTROLLER 102
CPU 119a
STORAGE/MEMORY 119b
GUI 140
141
Filter/ Data Processing
Data Base 124
122
Classifier
120
EC, PH, Tem, ORP, XRF, Vision/ Imaging...
Fertilizer Sys Dose Monitoring U1 ... Um
130
Climate Control Sys 132 H1 ... Hn
ERP (Log) 134
110
Robot Data Collection
Intervention Talk
Data collection all spectrum
Hammers Sys 112
112x
RFS conveyor 116a
NFT Conveyor 116b
Other Growing Beds 116c
Type of Unit (U)
Sensor command lines / Communication bus 104
108
Hn
H2
H1
108a
Ambient Sensors
106
Um
U2
U1

FIG. 1

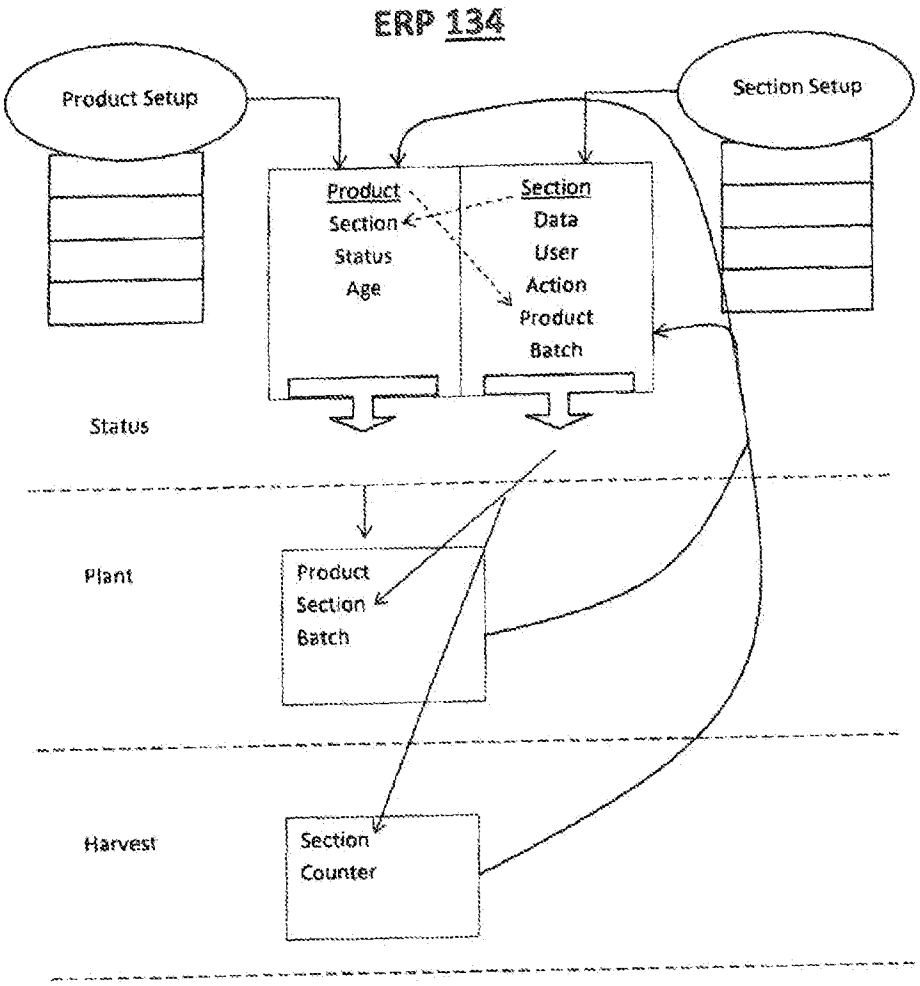

ERP 134
Product Setup
Section Setup
Product
Section
Status
Age
Section
Data
User
Action
Product
Batch
Status
Plant
Product
Section
Batch
Harvest
Section
Counter

FIG. 2A

Robot Control

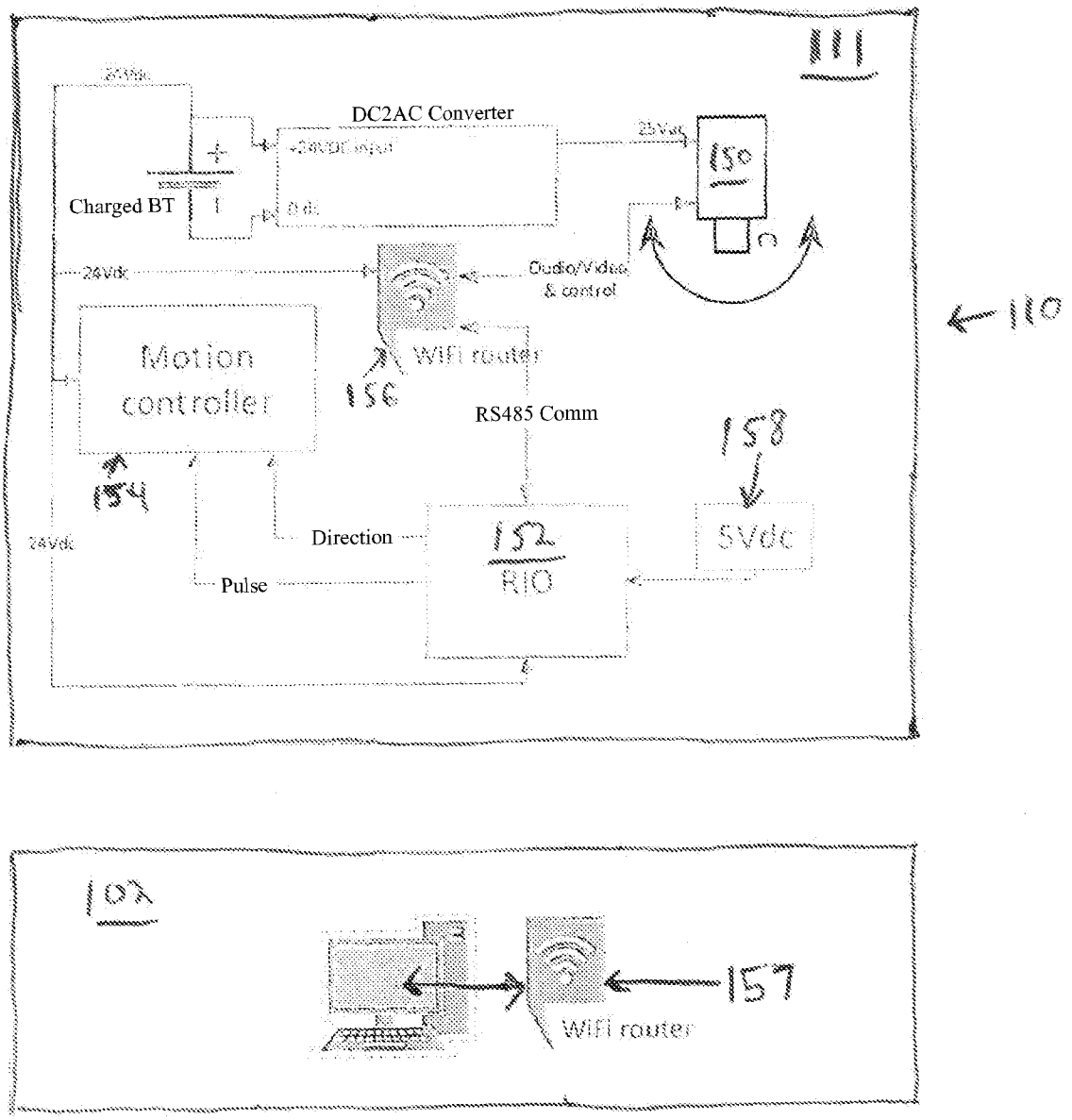
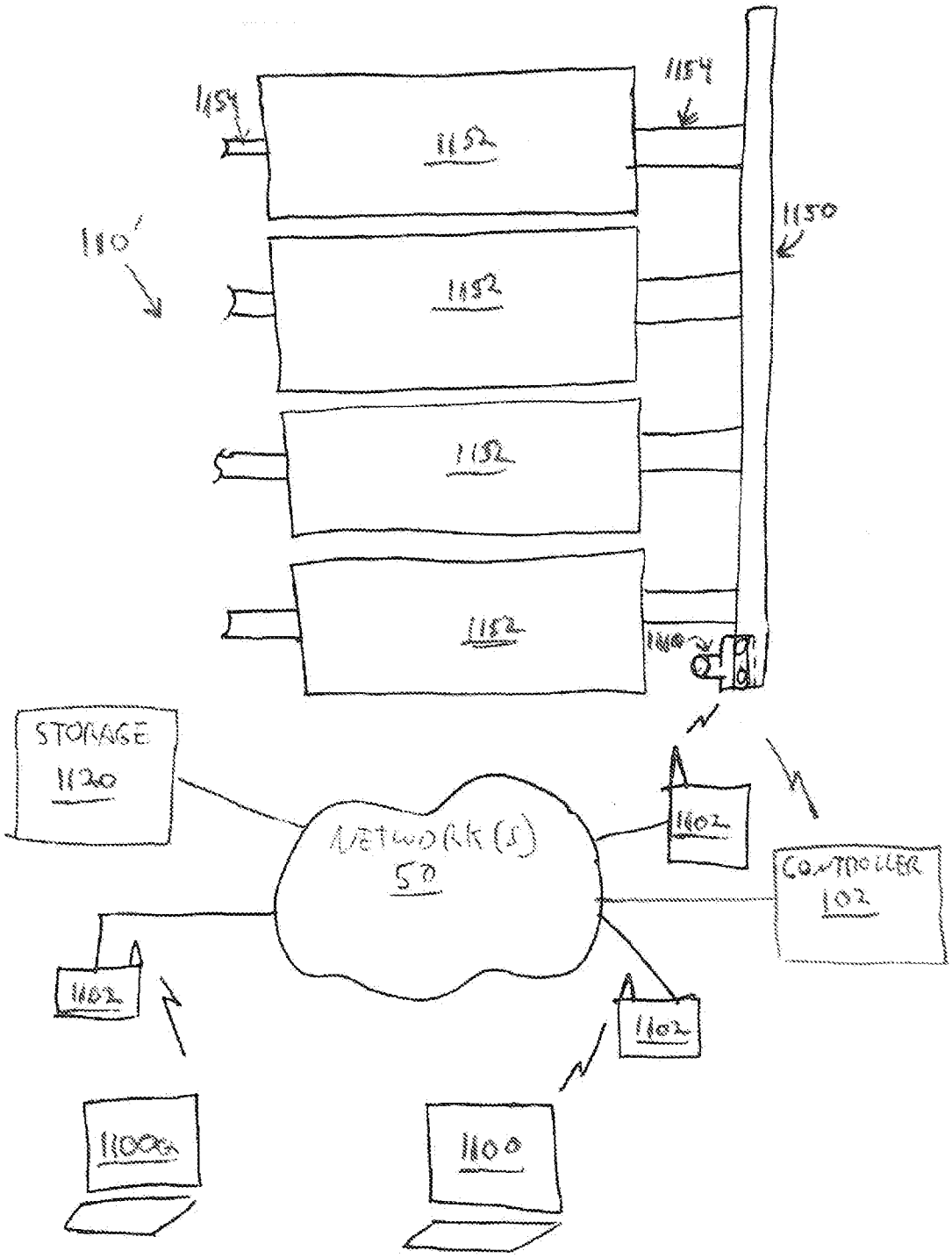


FIG. 2B

FIG. 2C


1154
1156
1152
1152
1152
1152
1150
1160
1102
1102
1102
1102
1100
1100
STORAGE
1120
NETWORK(S)
50
CONTROLLER
102

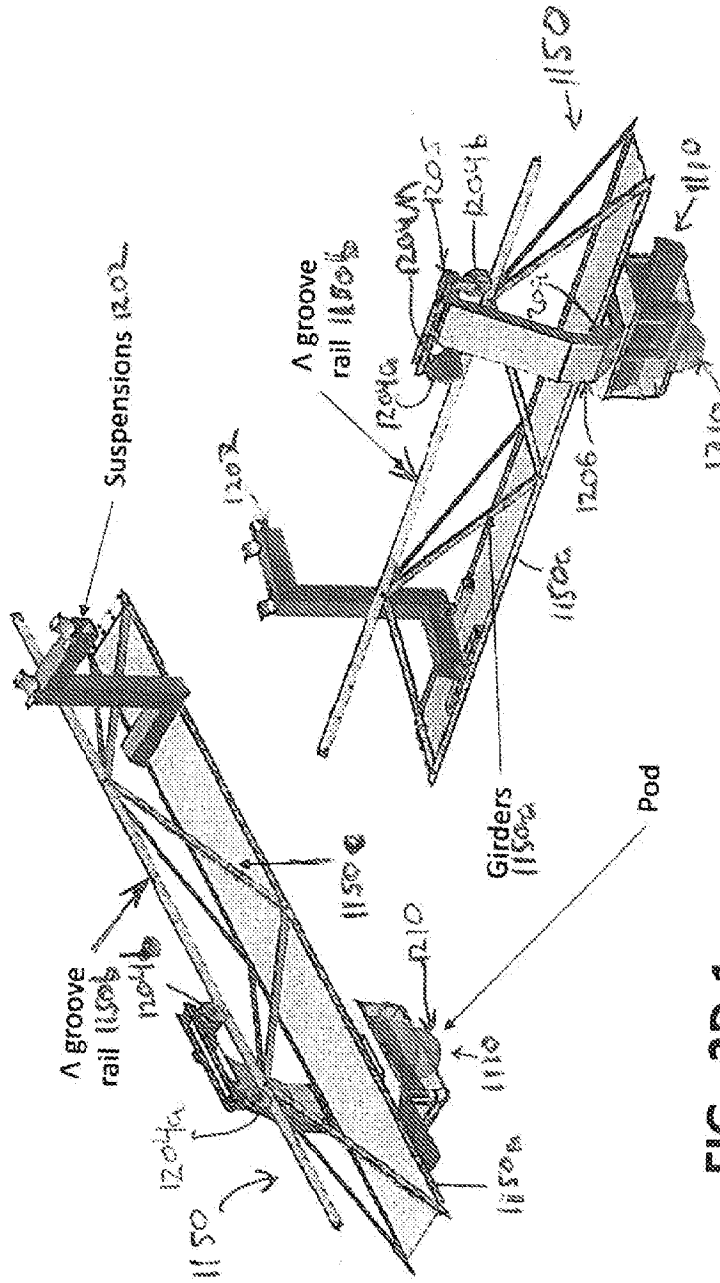


FIG. 2D-1

FIG. 2D-2

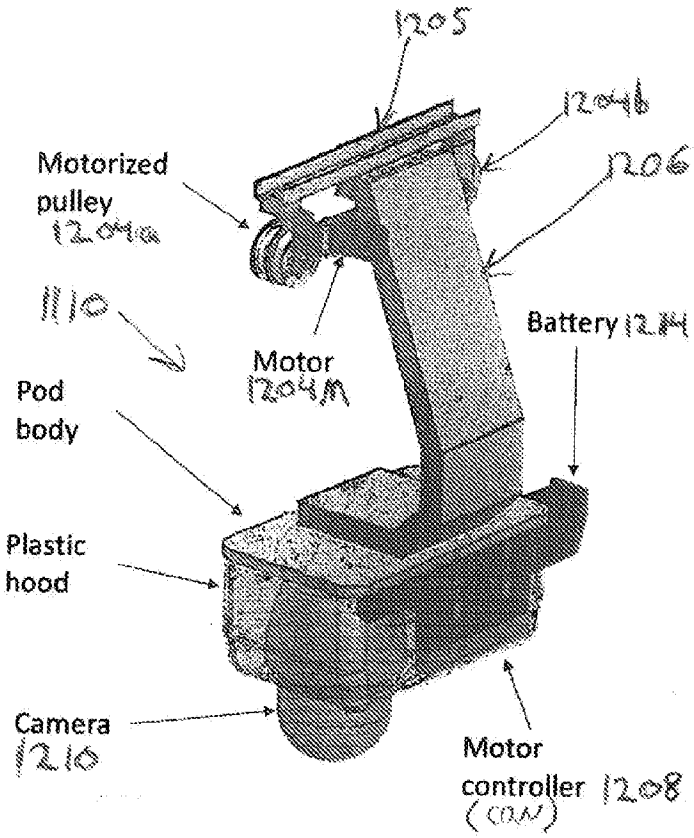

1205
1204b
1206
Motorized pulley 1204a
1110
Motor 1204M
Battery 1214
Pod body
Plastic hood
Camera 1210
Motor controller (CCM) 1208

FIG. 2D-3

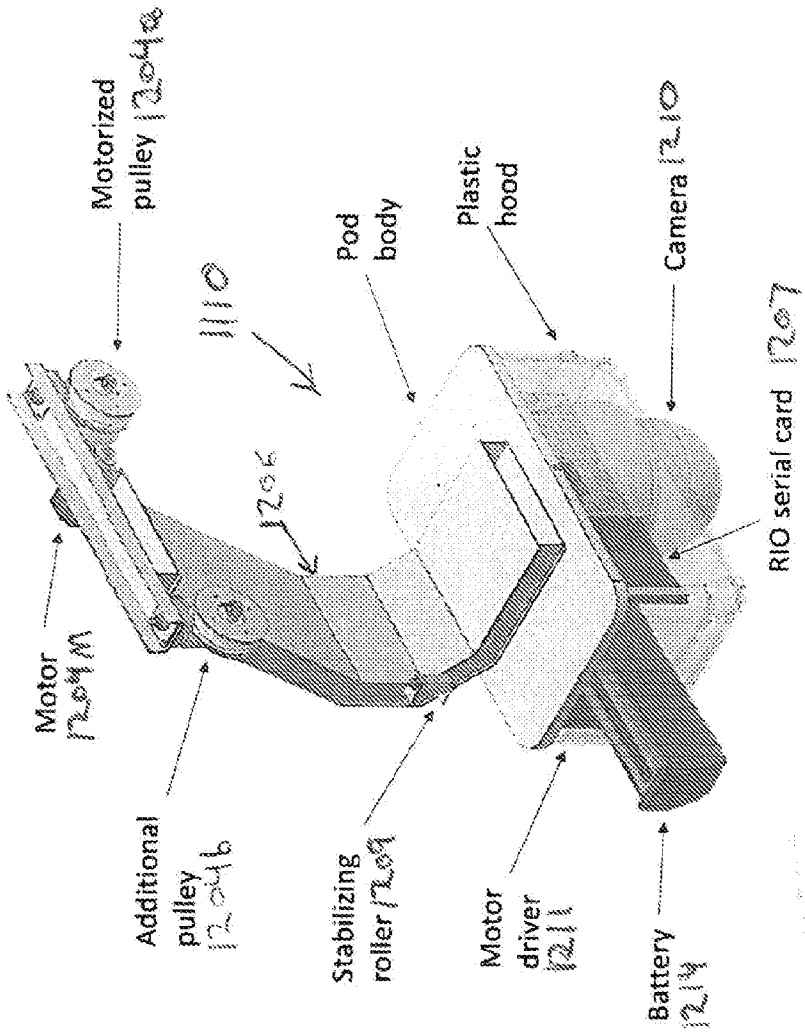

Motorized pulley 1204a
1110
Pod body
Plastic hood
Camera 1210
RIO serial card 1207
1206
Motor 1204M
Additional pulley 1204b
Stabilizing roller 1209
Motor driver 1211
Battery 1214

FIG. 2D-4

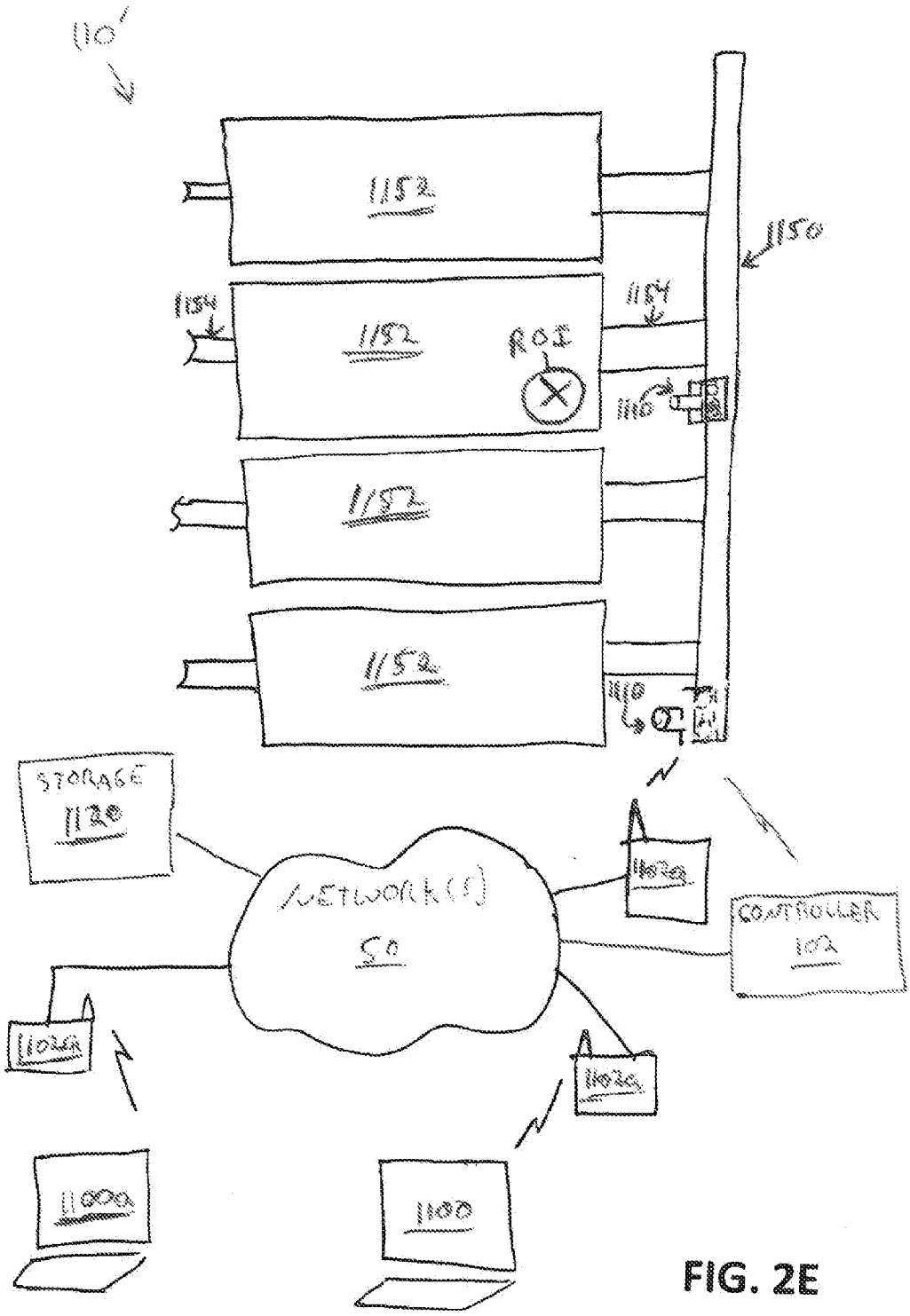

110'
1152
1150
1154
1152
ROI
1154
1116
1152
1152
1110
STORAGE
1120
NETWORK(S)
50
1102a
COMPUTER
102
1102a
1102a
1100a
1100

FIG. 2E

Process definitions:

Homing stations: A location on the rail with ID indication. Each home has a different I.D. Number.

Region Of Interest: R.O.I.

Reference Point identification: R.P identification

Reference Point identification number: R.P. - I.D.

Preset: A point with definitions spatial coordinates positioning (for instance: - "X", "Y" and "Z" coordinates), defined PTZ, defined R.P. and defined R.O.I.

Time interval: The time delay between Preset #N to Preset #(N+1).

Procedure: A group of presets, each one with specified tasks, that are executed consecutively. The time between every two presets is "Time interval".

Schedule: Defines the timetable to perform the procedures.

FIG. 2F-1

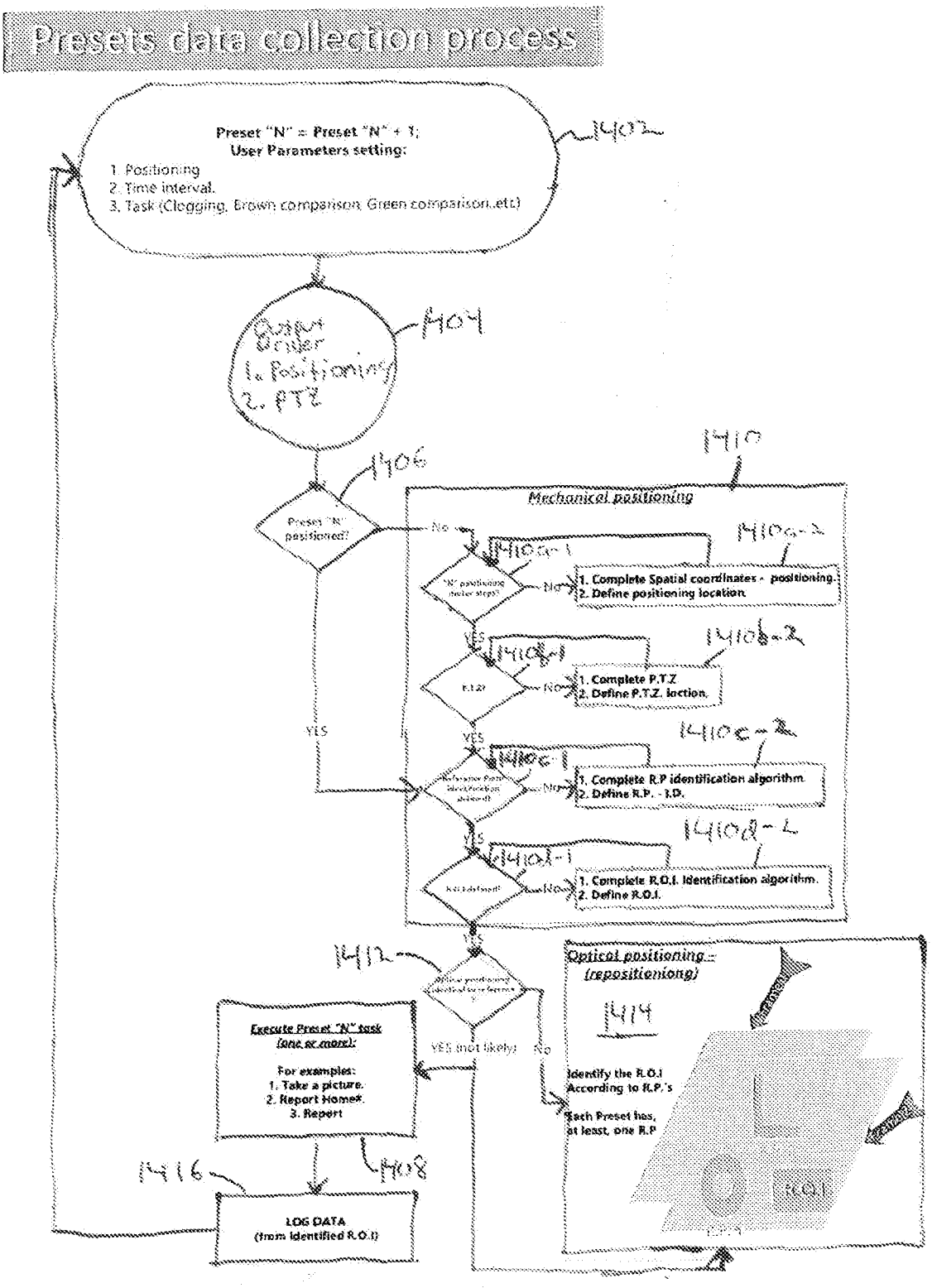

Presets data collection process
Preset "N" = Preset "N" + 1;
User Parameters setting:
1. Positioning
2. Time interval.
3. Task (Clogging, Brown comparison, Green comparison,ett.)
1402
Enter Order
1. Positioning
2. PTZ
1404
1406
Preset "N" positioned?
No
YES
1410
Mechanical positioning
1410a-1
"N" positioning motor steps?
No
1410a-2
1. Complete Spatial coordinates - positioning.
2. Define positioning location.
YES
1410b-1
P.T.Z?
No
1410b-2
1. Complete P.T.Z
2. Define P.T.Z. loction.
YES
1410c-1
No
1410c-2
1. Complete R.P identification algorithm.
2. Define R.P. - I.D.
YES
1410d-1
No
1410d-2
1. Complete R.O.I. identification algorithm.
2. Define R.O.I.
1412
YES (not likely)
No
Optical positioning - (repositioning)
1414
Identify the R.O.I According to R.P.'s
Each Preset has, at least, one R.P
R.O.I
Execute Preset "N" task (one or more):
For examples:
1. Take a picture.
2. Report Home#.
3. Report
1408
1416
LOG DATA
(from identified R.O.I)

FIG. 2F-2

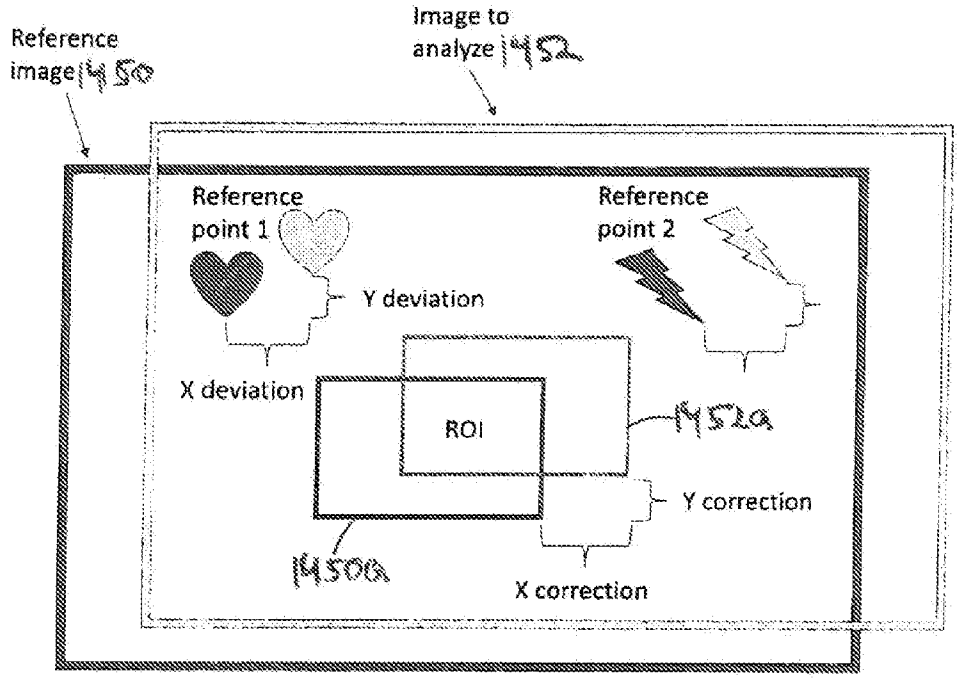

Optical positioning
Reference image 450
Image to analyze 452
Reference point 1
Reference point 2
Y deviation
X deviation
ROI
452a
Y correction
450a
X correction

FIG. 2F-3

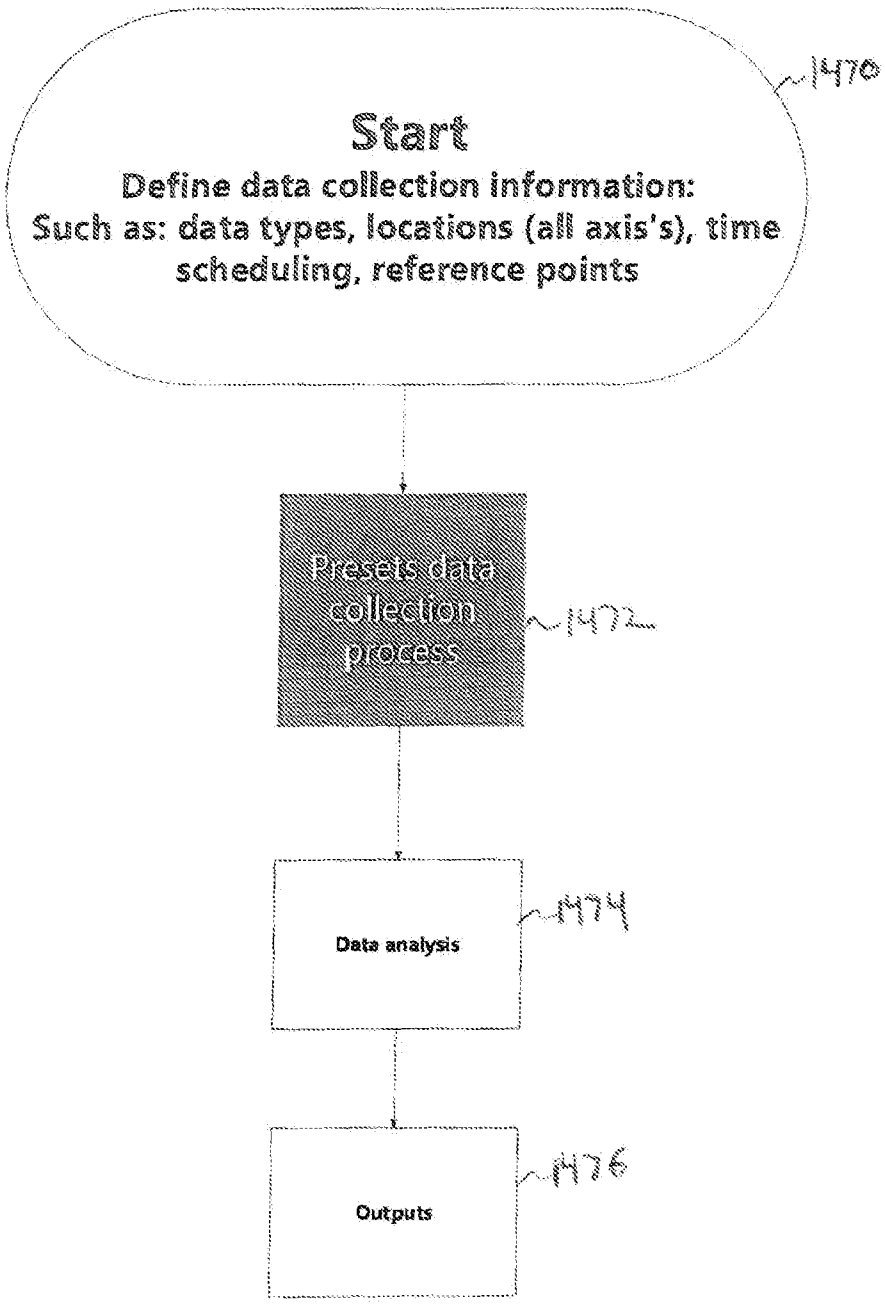
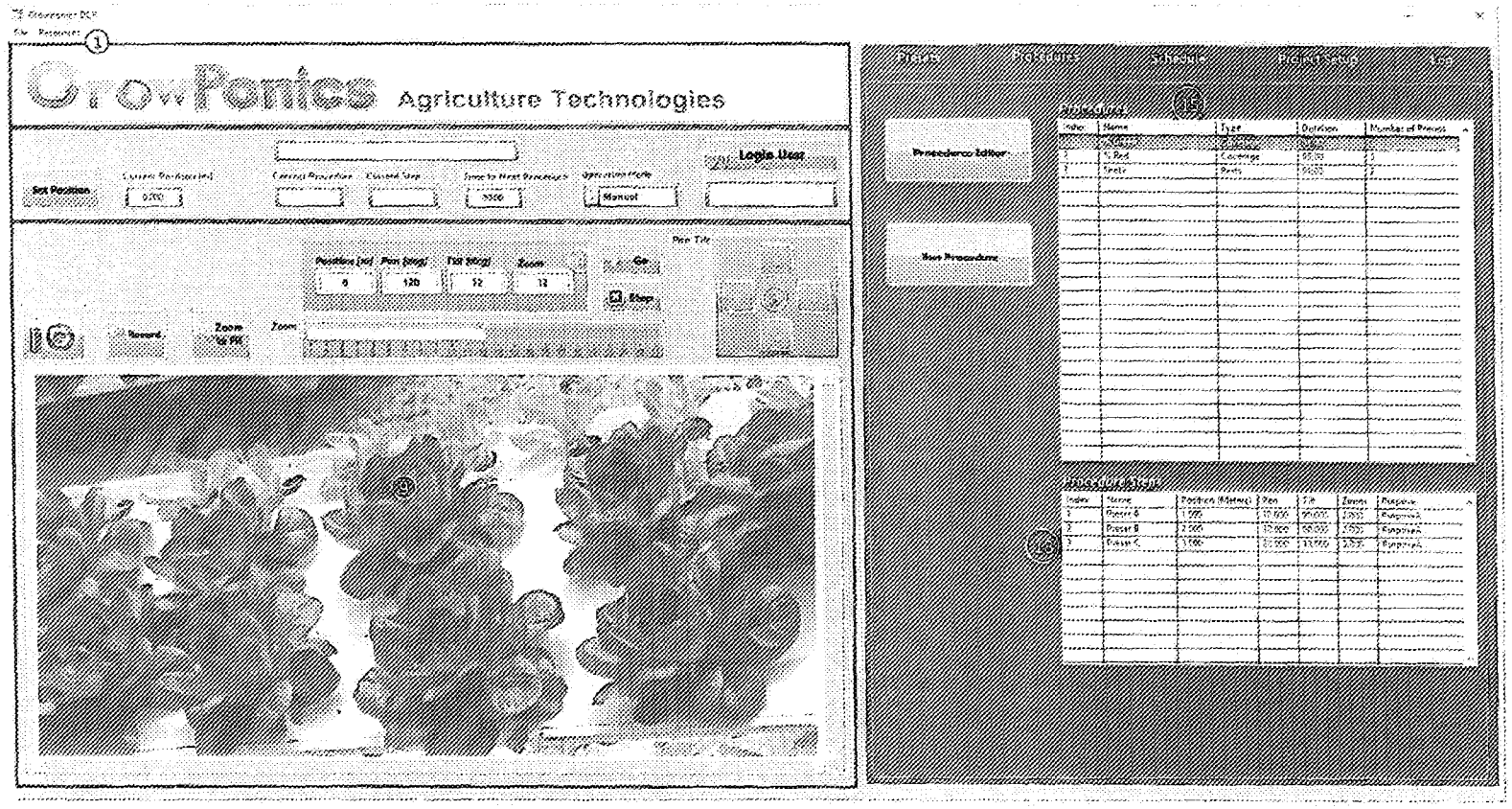

Start
Define data collection information:
Such as: data types, locations (all axis's), time scheduling, reference points
1470
Presets data collection process
1472
Data analysis
1474
Outputs
1476

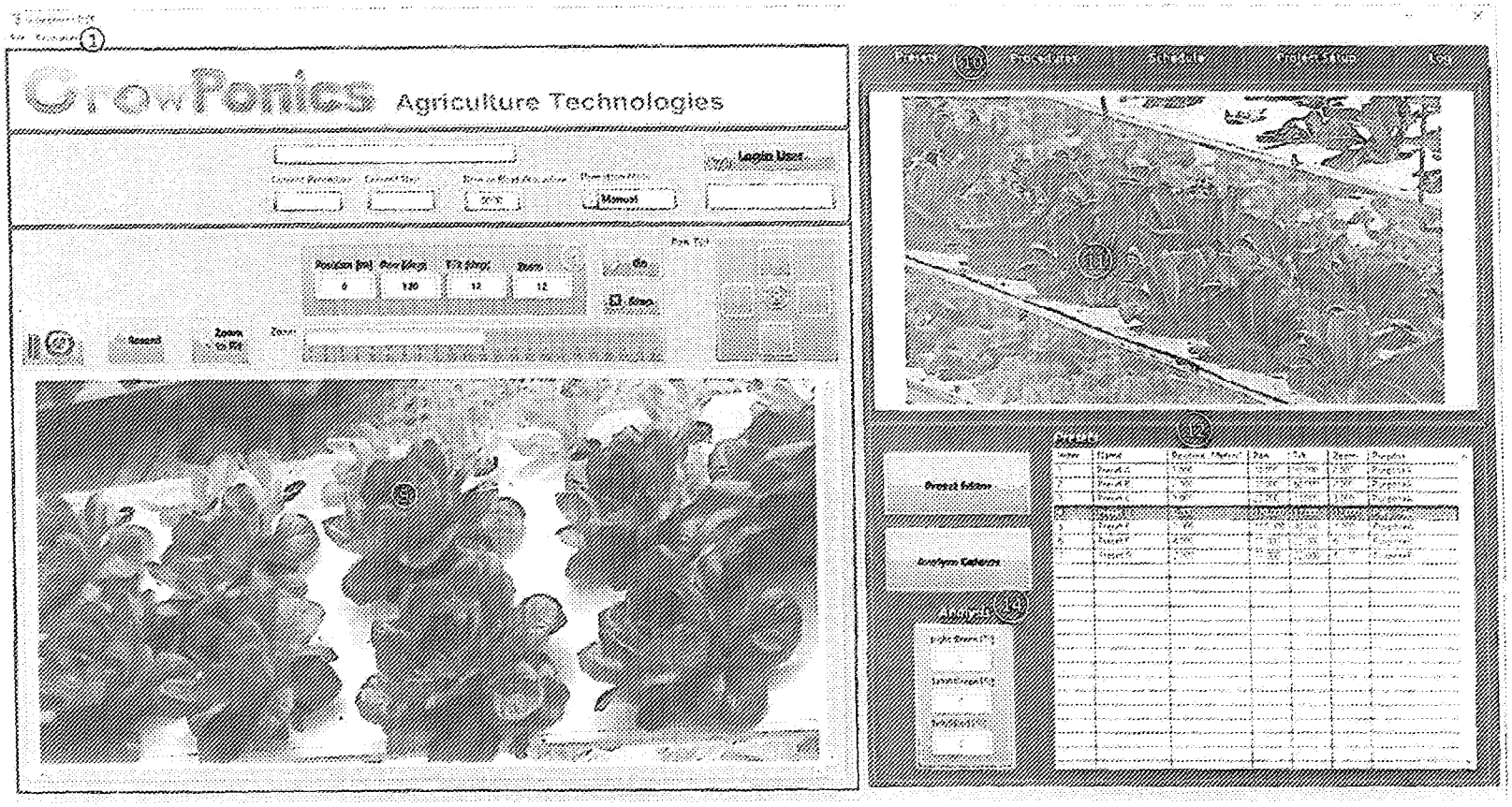
FIG. 2F-4

The right half of the GUI is divided to tabs (10). In the Presets tab, the current presets are displayed in a table (12). Presets can be added, deleted or edited by using the Preset Editor (13). In the preset editor, the user selects the preset's coordinates, region of interest (ROI) and a thumbnail of view from this preset is saved to be displayed later in (11). A sample of a quick analysis of the preset can be performed in (14).



In the procedures tab, the procedures are displayed in a table (15) and the preset steps of the procedures are in table (18). Procedures' steps can be edited with the procedure editor (16). The procedures are run manually (17) or on a daily / weekly schedule. The iteration of the steps is showed in 5. The menu bar (1) opens file settings and the resource manage to adjust network settings.

FIG. 2G-1



The left half of the GUI is dedicated to system status and manual camera control. The coordinates of the robot are composed of a linear position on the rail plus PTZ (pan tilt zoom) values, and are displayed in (4). The user can change these coordinates and press on Go to send there the robot, or press stop to halt its movement. The zoom can also be controlled by the zoom bar (3), and the pan / tilt can be controlled with the arrows (8). The current camera view is displayed in an image box (9). Snapshots or videos can be recorded (2). The image box (9) has a digital zoom capability that can be restored by pressing Zoom- to-Fit (3). The operation mode, manual or automatic can be selected (6), and the user can be changed from a User to an Administrator (7).

FIG. 2G-2

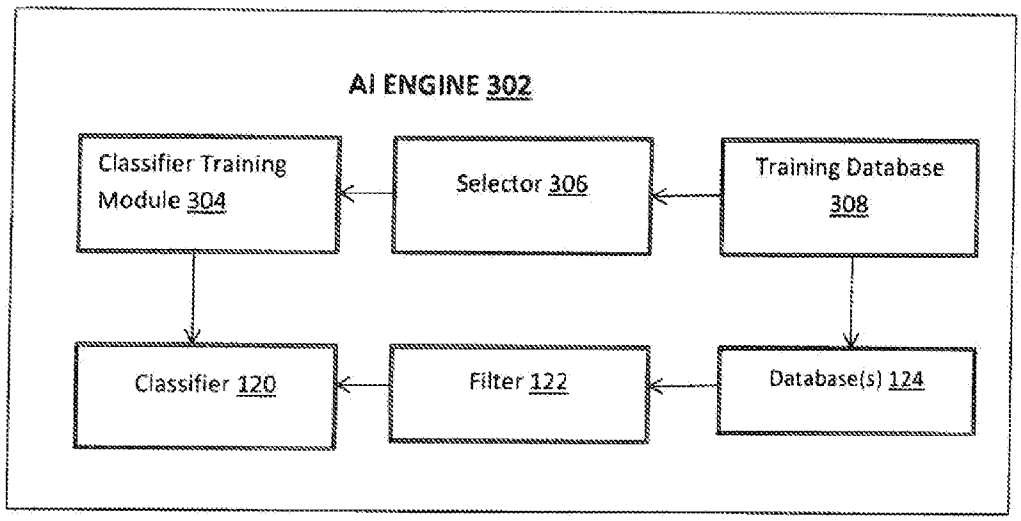

AI ENGINE 302
Classifier Training Module 304
Selector 306
Training Database 308
Classifier 120
Filter 122
Database(s) 124

FIG. 3

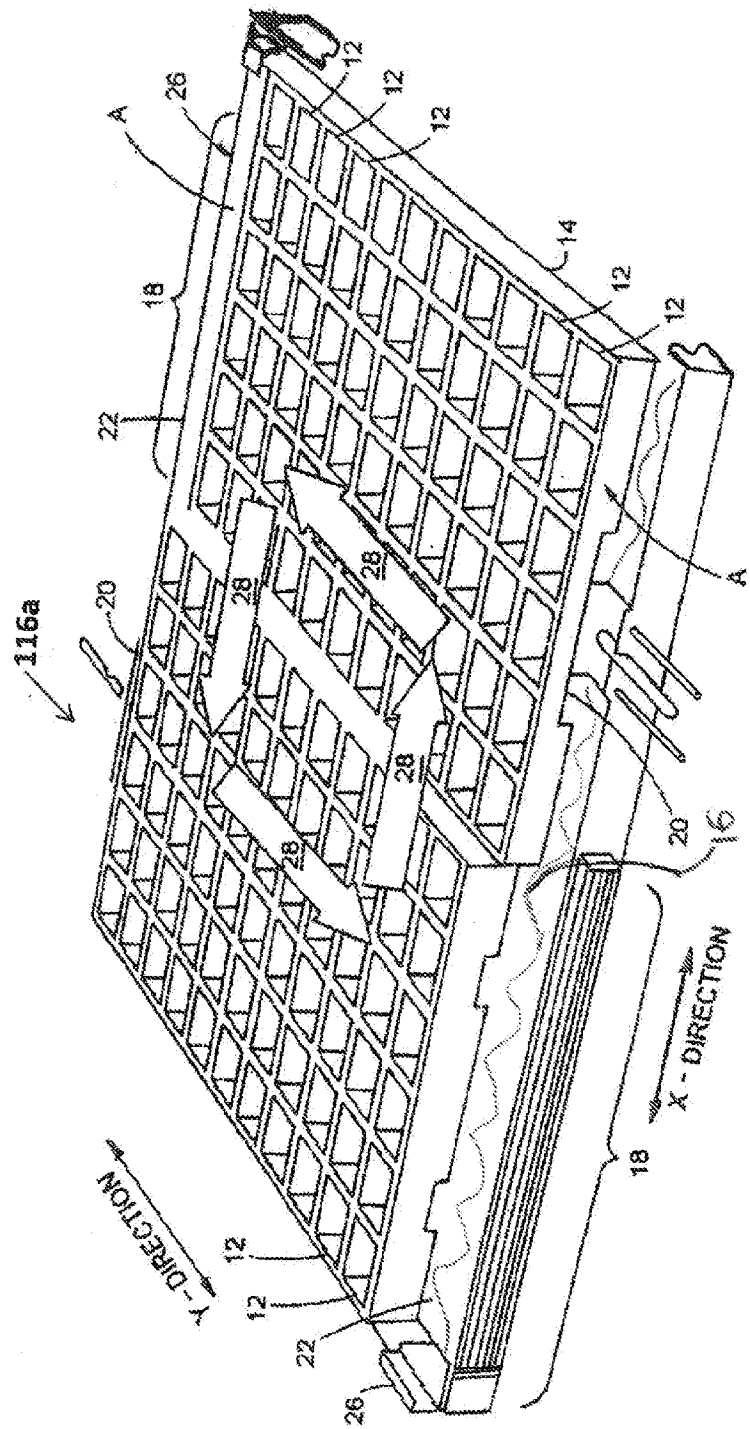

116a
A
A
12
12
12
12
12
12
14
16
18
18
20
20
22
22
26
26
28
28
28
28
X - DIRECTION
Y - DIRECTION

FIG. 4A

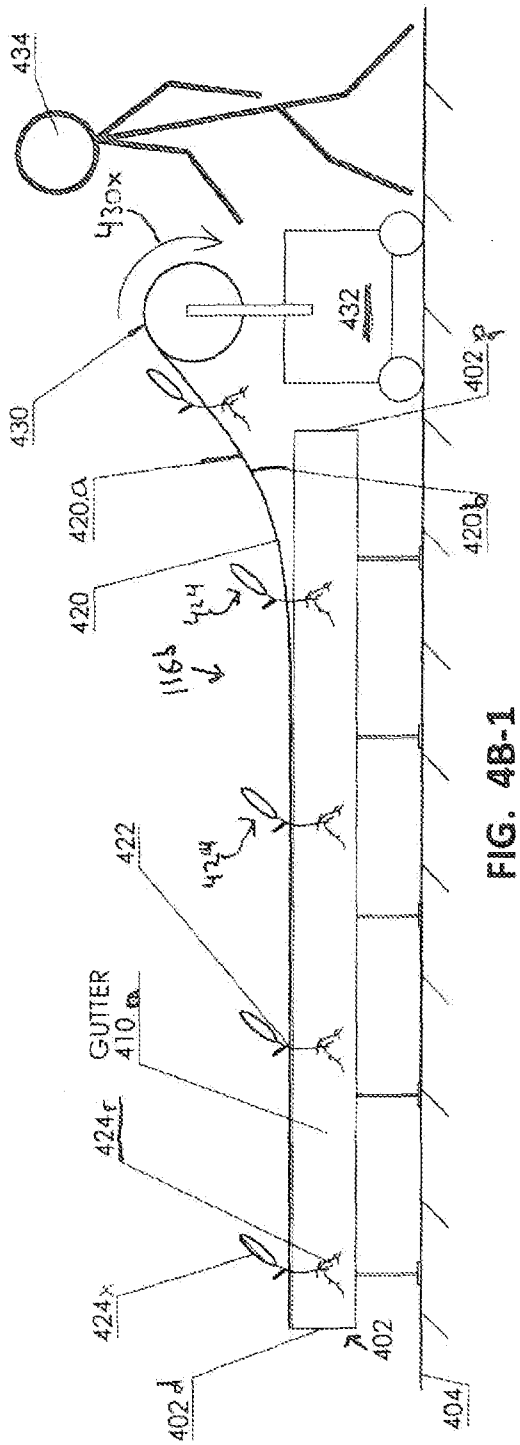


FIG. 4B-1

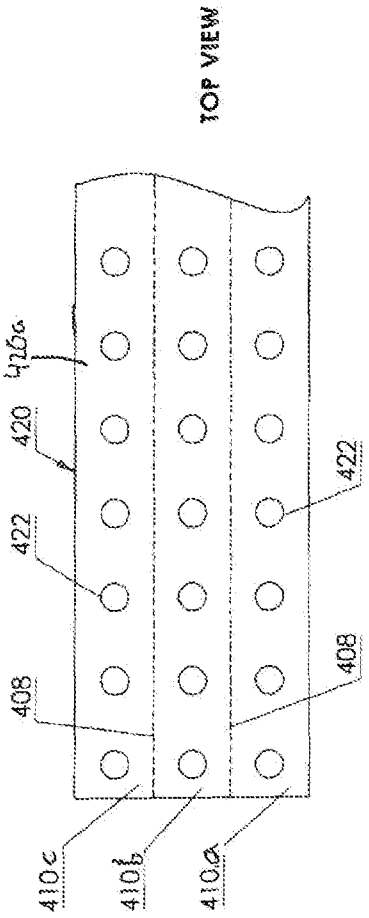


FIG. 4B-2

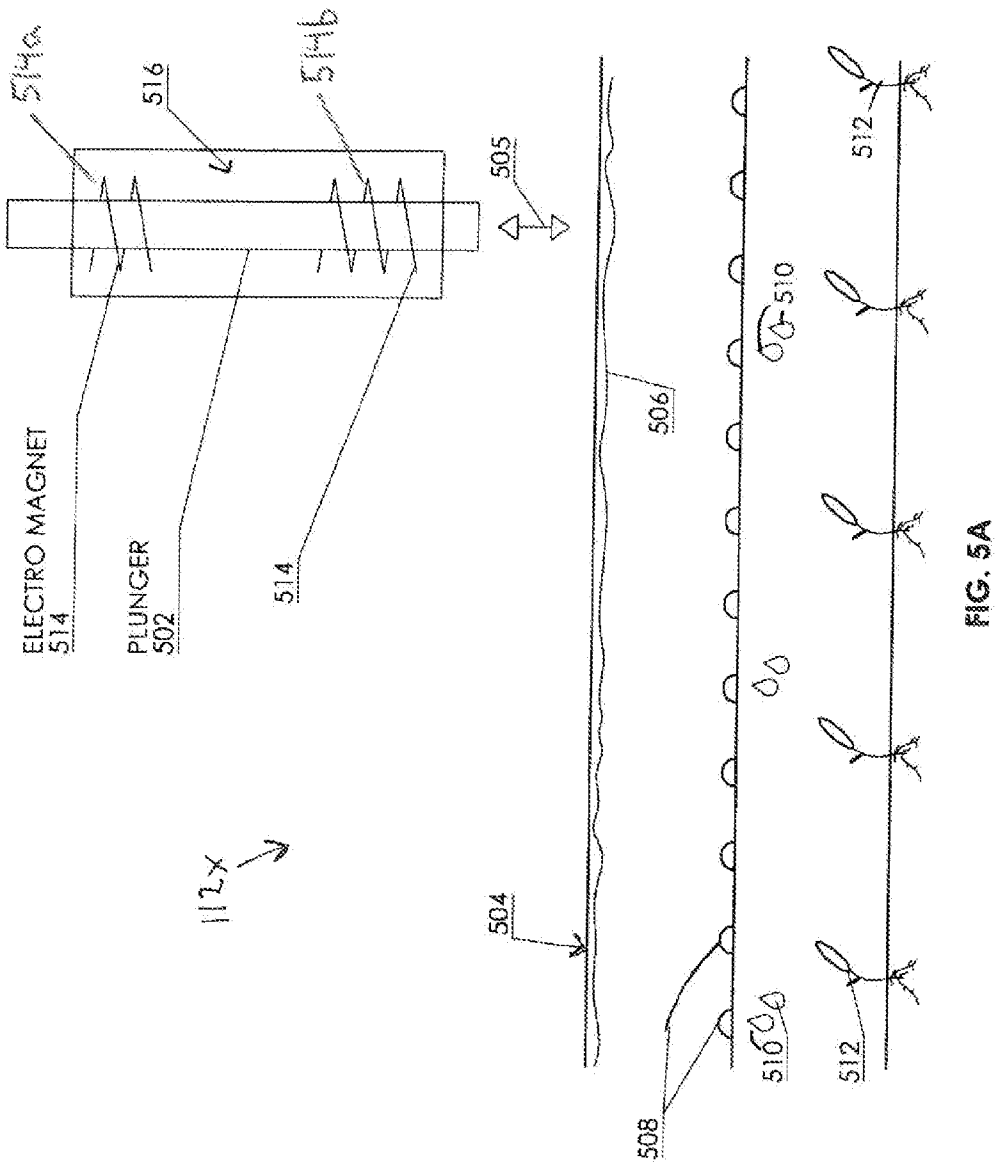

514a
516
514b
505
ELECTRO MAGNET
514
PLUNGER
502
514
506
510
512
112x
504
508
510
512

FIG. 5A

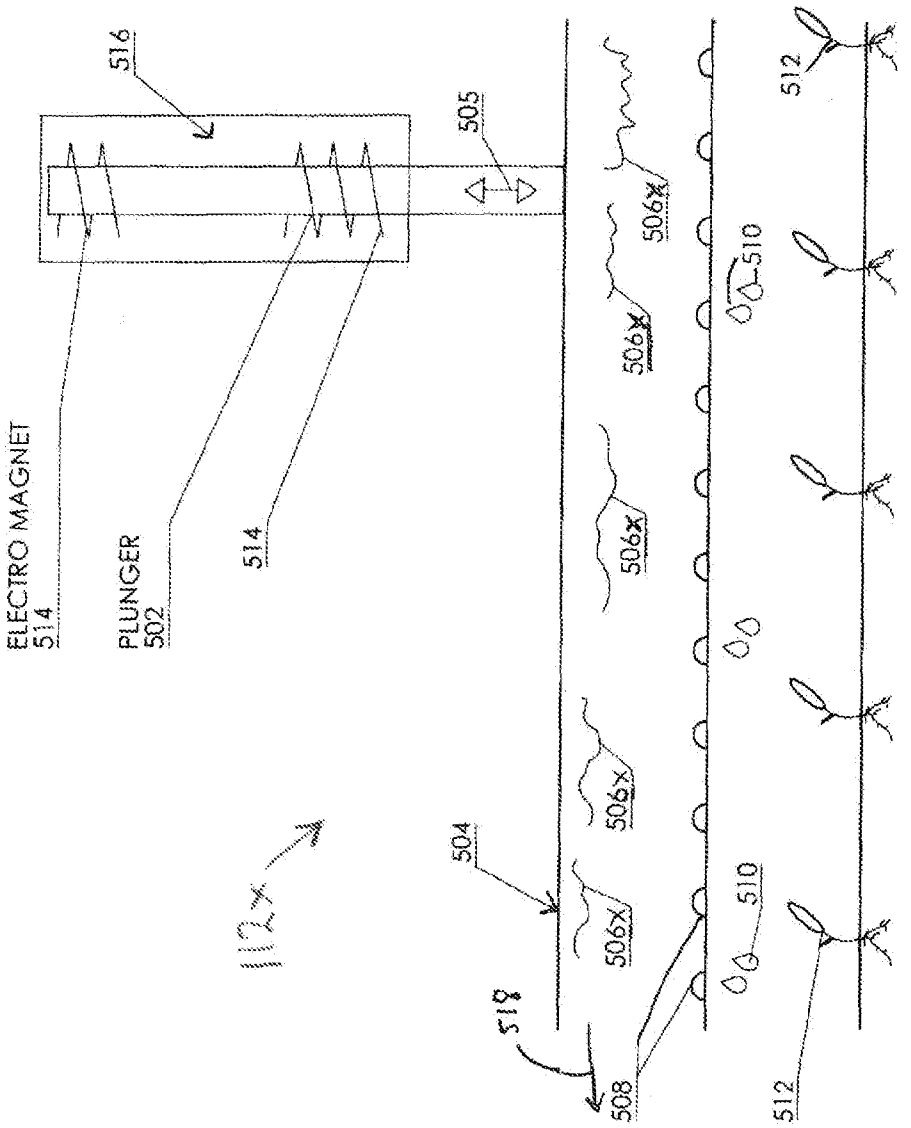

ELECTRO MAGNET
514
PLUNGER
502
514
516
505
506x
506x
506x
506x
510
510
504
518
508
512
512
112

FIG. 5B

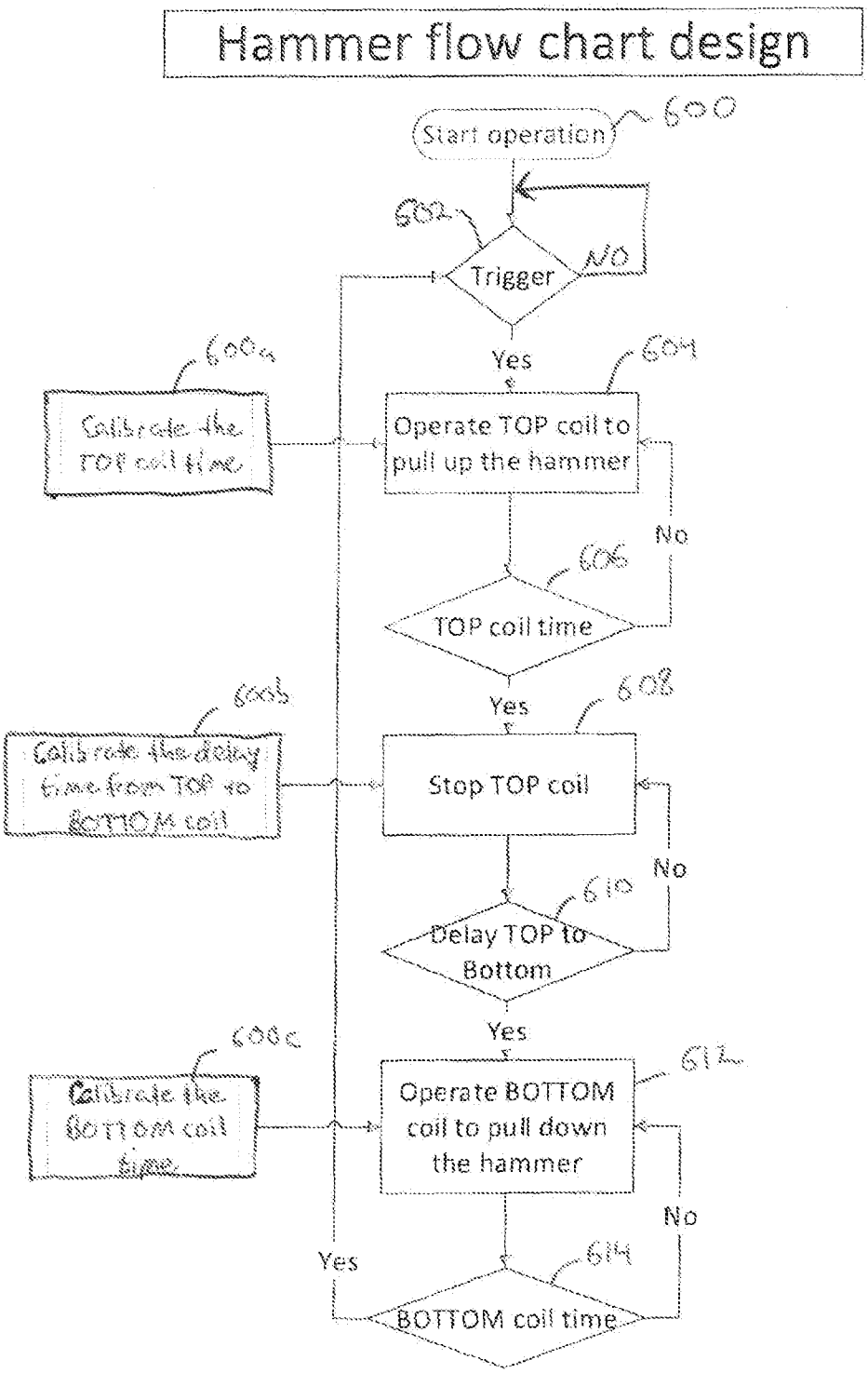

Hammer flow chart design
Start operation
600
602
Trigger
NO
Yes
604
Operate TOP coil to pull up the hammer
No
606
TOP coil time
Yes
608
Stop TOP coil
No
610
Delay TOP to Bottom
Yes
612
Operate BOTTOM coil to pull down the hammer
No
614
BOTTOM coil time
Yes
600a
Calibrate the TOP coil time
600b
Calibrate the delay time from TOP to BOTTOM coil
600c
Calibrate the BOTTOM coil time

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2019/053121

A. CLASSIFICATION OF SUBJECT MATTER
IPC (20190101) G05D 1/02
CPC (20130101) G05D 1/0255, G05D 1/0274
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (20190101) G05D 1/02
CPC (20130101) G05D 1/0255, G05D 1/0274

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Databases consulted: Esp@cenet, Google Patents
Search terms used: greenhouse robot compare data in reference point;

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005046373 A1 ALDRED MICHEAL DAVID 03 Mar 2005 (2005/03/03) ¶ 8, 16, 37-42, 47-48, 56, 58, 68, 96	1-18

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 Jul 2019	31 Jul 2019

Name and mailing address of the ISA:	Authorized officer
Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. pctoffice@justice.gov.il	MARCOWITZ Noam Telephone No. 972-73-3927224

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/053121

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
US 2005046373 A1	03 Mar 2005	US 2005046373 A1	03 Mar 2005
		US 7053580 B2	30 May 2006
		AU 2002337359 A1	19 May 2003
		EP 1440355 A2	28 Jul 2004
		GB 0126499 D0	02 Jan 2002
		JP 2005507537 A	17 Mar 2005
		JP 3955569 B2	08 Aug 2007
		WO 03039314 A2	15 May 2003
		WO 03039314 A3	16 Oct 2003