

SYSTEM AND METHOD FOR REFUELING UNMANNED GROUND VEHICLES

FIELD OF THE INVENTION

- 5 [001] The present invention relates to a system and method for refueling unmanned ground vehicles. More particularly, the invention relates to a system and method for refueling a plurality of unmanned ground vehicles by optimizing the refueling schedule.

10 BACKGROUND OF THE INVENTION

- [002] Unmanned ground vehicles ("UGVs") have been actively developed for both civilian and military use to perform dull, dirty and dangerous activities. For military purposes, UGVs have been used for performing a range of applications, such as for reconnaissance, surveillance, or combat missions, or
15 for explosive ordnance disposal (EOD). For civilian purposes, the range of applications includes monitoring weather conditions, border patrols, and industrial or commercial usage such as harvesting crops, as well as rescue operations.

- 20 [003] Currently, UGV power sources may be a combination of fuel, rechargeable lead-acid or Ni-Cad batteries, or lithium ion batteries or fuel cells. As UGVs operate in terrain which is unstructured and uncertain (for example, hills, trenches, sand, gravel, etc.), power limitations can cause significant reliability issues. More importantly, the endurance and range of distance a
25 UGV can travel is impacted by power or fuel limitations. Although, in general, the operational runtime of UGVs can be estimated based on the power capacity, unstructured and uncertain terrain may affect the estimated operational runtime.

[004] To circumvent the reliability issue in the range and endurance of the UGVs, real time monitoring systems of the power level of UGVs have been implemented. The status of the power level is transmitted to a base station which will subsequently either recall the UGV back to base for refueling or recharging or have the UGV continue with the mission. When a UGV is unable to return back to base in time for recharging or refueling, the UGV is abandoned and a replacement UGV is further deployed to continue with the mission. Time is therefore wasted when the UGV has to return to base for recharging.

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[005] In some cases, the base station will move closer to the deployed UGVs so that the UGVs may be able to return to base in time for recharging and refueling. However, this increases the probability of the base station being compromised in reconnaissance or surveillance missions.

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[006] There is, therefore, a need for a method or a system that provides an optimal scheduling for recharging UGVs without any of the problems described above.

20 [007] Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the state of the art or the common general knowledge in the relevant art anywhere on or before the priority date of the disclosure and claims herein. All statements as to the date or representation as to the contents of these documents is based on the information available to the applicants and does not constitute any admission as to the correctness of the date or contents of these documents.

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OBJECTS OF THE INVENTION

[008] It is an object of the present invention to overcome, or at least substantially ameliorate, the disadvantages and shortcomings of the prior art.

5 [009] It is also an object to provide a method and system for refueling unmanned ground vehicles.

[010] It is a further object of the invention to provide a system and method for refueling a plurality of unmanned ground vehicles by optimization.

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[011] Other objects and advantages of the present invention will become apparent from the following description, taken in connection with the accompanying drawings, wherein, by way of illustration and example, an embodiment of the present invention is disclosed.

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SUMMARY OF THE INVENTION

[012] According to the present invention, there is provided a system for optimizing the refueling of a plurality of unmanned ground vehicles (UGVs) comprising a modular sensing unit mounted on each of the plurality of UGVs, a
20 base station, and a mobile refueling station. The modular sensing unit comprises (a) a power supply sensor, (b) a location sensor, and (c) a transceiver for obtaining and transmitting power supply levels and locations of each UGV. The base station has a processor to receive the power supply levels and the locations of each of the plurality of UGVs and to determine the
25 power supply level and the distance between the base station and the UGV for each UGV. The mobile refueling station is capable of refueling a UGV at a predetermined location. The base station processor determines a refueling protocol.

[013] In one embodiment of the invention, a system for optimizing the refueling of a plurality of unmanned ground vehicles (UGVs) comprises:

5 a plurality of UGVs, each UGV having a modular sensing unit thereon, the modular sensing unit comprising (a) a power supply sensor, (b) a location sensor, and (c) a transmitter coupled to said power supply sensor and said location sensor, for receiving and transmitting a power supply level and a location of each UGV;

10 a base station having a first receiver for receiving the power supply level and the location of each of the plurality of UGVs, a processor coupled to the receiver for storing the power supply levels and for determining the distance between the base station and the UGV, for each UGV, and a transmitter coupled to said processor; and

15 a mobile refueling station capable of refueling a UGV at a predetermined location, said mobile refueling station having a second receiver for receiving commands from said processor,

wherein the base station processor generates commands for said mobile refueling station based upon a refueling protocol.

20 [014] In another embodiment of a system of the invention, the base station initiates the deployment of the mobile refueling station when the power supply level of a UGV reaches or is less than a predetermined lower value and the distance between the UGV and the base station is equal to or greater than a predetermined value.

25 [015] In yet another embodiment of a system of the invention, the predetermined lower value of the power supply of the UGV is in the range of from about 10% to about 20% of the total power supply of the UGV.

[016] In yet another embodiment of a system of the invention, the predetermined distance between the UGV and the base station is in the range of from about 2 to about 10 km.

- 5 [017] In yet another embodiment of a system of the invention, the base station determines the location to deploy the mobile refueling station based upon the power supply readings of other UGVs within the vicinity of the UGV.

- 10 [018] In yet another embodiment of a system of the invention, the power supply levels of the other UGVs within the vicinity of the UGV are each within the range of from about 10 to about 50% of the total power supply of each of the other UGVs.

- 15 [019] In yet another embodiment of a system of the invention, the base station will activate a refueling tanker to the UGV when the power supply level of the UGV reaches a predetermined level and the UGV is greater than a predetermined distance from the base station.

- 20 [020] In yet another embodiment of a system of the invention, the base station is mobile.

- [021] In yet another embodiment of a system of the invention, the refueling protocol is further determined based on mission configuration of the plurality of UGVs.

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- [022] In yet another embodiment of a system of the invention, the mobile refueling station is sent to a predetermined location by an aerial vehicle.

[023] In yet another embodiment of a system of the invention, the mobile power refueling station further comprises at least a battery cartridge for recharging the UGV.

- 5 [024] In yet another embodiment of a system of the invention, the mobile power refueling station further comprises a global positioning sensor for determining its location data.

- 10 [025] In yet another embodiment of a system of the invention, the mobile power refueling station further comprises a communication interface for transmitting location data to the base station.

- 15 [026] In yet another embodiment of a system of the invention, the mobile power refueling station further comprises a docking sensor for guiding the UGV to a docking station for recharging the power supply of the UGV.

- 20 [027] In yet another embodiment of a system of the invention, the mobile power refueling station further comprises shock absorbing means on the exterior of the refueling station to withstand adverse shocks to the refueling station upon landing on ground.

[028] In yet another embodiment of the invention, a method for optimizing the refueling at least one of a plurality of UGVs comprises:

- 25 obtaining power supply levels of each of the plurality of UGVs;
 transmitting the power supply levels of each of the plurality of UGVs to a base station;
 obtaining locations of each of the plurality of UGVs;
 transmitting the locations of each of the plurality of UGVs to the base station; and

determining a refueling protocol for one of said plurality of UGVs based upon the received power supply levels and locations of each of said UGVs.

- 5 [029] In yet another embodiment of a method of the invention, a mobile refueling station for a UGV is deployed based on the power supply levels and the distances between the UGVs and the base station.

- 10 [030] In yet another embodiment of a method of the invention, the method further comprises determining the refueling protocol by activating the deployment of the mobile refueling station when the UGV reaches a predetermined power supply value and a predetermined distance value between the UGV and the base station.

- 15 [031] In yet another embodiment of a method of the invention, the method further comprises determining a location for the mobile refueling station, the location of the mobile refueling station deployed determined being based upon the power supply levels of other UGVs within the vicinity of the UGV.

- 20 [032] In yet another embodiment of a method of the invention, the predetermined power supply level of the UGV is within the range of from about 10 to about 20% of the power supply of the UGV.

- 25 [033] In yet another embodiment of a method of the invention, the predetermined distance between the UGV and the base station is within the range of from about 2 to about 10 km.

- [034] In yet another embodiment of a method of the invention, the power supply levels of the other UGVs within the vicinity of the UGV are within the

range of from about 10 to about 50% of the total power supply of each of the other UGVs.

[035] In yet another embodiment of a method of the invention, the method
5 further comprises deploying a refueling tanker to the UGV when the UGV reaches a predetermined power supply level and is outside the range of the predetermined distance between the UGV and the base station.

[036] In yet another embodiment of a method of the invention, the base station
10 is mobile.

[037] In yet another embodiment of a method of the invention, the refueling protocol is further determined based on mission configuration of the plurality of UGVs.
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[038] This invention may also be said broadly to consist in the parts, elements and features referred to or indicated in the specification of the application, individually or collectively, and any or all combinations of any two or more of said parts, elements or features, and where specific integers are mentioned
20 herein which have known equivalents in the art to which this invention relates, such known equivalents are deemed to be incorporated herein as if individually set forth.

BRIEF DESCRIPTION OF THE DRAWINGS

25 [039] In order that the invention may be better understood and put into practical effect, reference will now be made to the accompanying drawings, in which:

[040] Figure 1 is a block diagram of an embodiment of a base station in accordance with the present invention;

[041] Figure 2 is a block diagram of an embodiment of a modular sensing unit
5 of an unmanned ground vehicle (UGV) in accordance with the present invention;

[042] Figure 3 is a flow diagram showing the method of optimizing the refueling of a plurality of UGVs;

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[043] Figure 4 is an illustration of a network formation of UGVs in a defense mission or situation;

[044] Figure 5 is a perspective view of a mobile refueling station (MRS) in
15 accordance with an embodiment of the present invention;

[045] Figure 6 is a side view illustrating the process of refueling between a UGV and the MRS;

20 [046] Figure 7 is a plan view illustrating the process of refueling between a UGV and the MRS.

DETAILED DESCRIPTION OF THE INVENTION

[047] The present invention will now be described in detail in connection with preferred embodiments with reference to the accompanying drawings.

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[048] The present invention relates to a system and method for optimizing the refueling of unmanned ground vehicles (UGVs). UGVs are autonomous vehicles, with humans baseling their actions or directly overseeing the tactical and mission oriented behaviors from a remote location. UGVs include a wide
10 range of sizes, types, capabilities and potential applications and are typically powered by a non-petroleum power pack, such as batteries or a fuel cell. The power pack supplies energy to drive the motor of the UGV, which in turn transfers power to the UGV to perform its intended use. For the reliable operation of UGVs, the management of energy and power usage in UGVs is
15 critical for operational use.

[049] Figure 1 is a block diagram showing an embodiment of a base station 10 for baseling UGVs when they are in use. Base station 10 includes a processor 12 and a wireless transceiver 22. Processor 12 includes a central processing
20 unit (CPU) (not shown) and may be a printed circuit board or a processor executing a set of program instructions stored on a computer readable storage medium such as random access memory (RAM), read only memory (ROM), magnetic storage medium, optical storage medium, or the like. Processor 12 can be a handheld device or a conventional computer such as a PC running on
25 an appropriate operating system. Processor 12 executes compatible instructions or software stored in memory 18.

[050] Base station 10 receives information via wireless transceiver 22. Wireless transceiver 22 includes an antenna 26 and a radio 24 for coupling to

processor 12. Wireless transceiver 22 allows a plurality of users to access the same communication medium to transmit and receive information from the UGVs. The use of communication techniques for the purpose of this invention is known to a person skilled in the art and will be understood by person skilled in the art to be any enabling technology for the purpose of transmitting and receiving information wirelessly. Some of these communication techniques may include FDMA (frequency Division Multiple Access), TDMA (Time Division Multiple Access), CSMA (Carrier Sense multiple Access), or CDMA (Code Division Multiple Access).

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[051] Base station 10 includes a communications module 16. Communications module 16 may include a baseler (not shown) for baseling the flow of incoming signals or information received from the wireless transceiver. Communications module 16 contains a radio (not shown) for processing the incoming signals and stores the incoming signal or information in the form of data in a data module.

[052] A display unit 19 providing a graphical user interface for a user of base station 10 displays the relevant parameters or critical information for the user to perform tasks. An input device (not shown) may also be connected with display unit 19 to allow the user to input instructions into processor 12.

[053] A data module 14 of base station 10 serves to process the incoming data received from communications module 16. Data module 14 also contains a database comprising predetermined parameters of variables. The database may contain tables or charts of predetermined readings, each reading corresponding to a certain set of instructions to be transmitted to each of the UGVs in response to the incoming signals or data received by wireless transceiver 22. The incoming signals or the data received via the communications module 16 is compared with these predetermined parameters

for processor 12 to execute scheduling tasks to the UGVs. The predetermined parameters may be, for example, position coordinate readings, power supply readings, distance measurements, mileage efficiency or odometer readings of the UGVs. For example, a power supply reading received by communications
5 module 16 will be compared with a predetermined power supply reading in the database of data module 14. If the power supply reading is lower than the predetermined power supply reading parameter in the database, processor 12 will execute a set of predetermined instructions for resupply or refueling the UGVs. The mechanics of activating the predetermined instructions will be
10 explained in detail below.

[054] Figure 2 illustrates an embodiment of a modular sensing unit 30. A modular sensing unit 30 is installed in each of the UGVs and includes a wireless transceiver 42 that includes a radio 46, and an antenna 44. A
15 processor 32 similar to the one for base station 10 is coupled with a wireless transceiver 42. Processor 32 may include a CPU, memory, and external I/O ports 38 for communication with other parts of the UGV, for example, the main processor (not shown) of the UGV. Modular sensing unit 30 may also be coupled with the motor baseler of the UGV to base the movements of the UGV.
20 Modular sensing unit 30, as its name suggests, is detachable from the UGV for servicing, maintenance and facilitating installation.

[055] Processor 32 of modular sensing unit 30 includes a location sensor 36 and a power supply sensor 34. Other sensors, for example, for odometer
25 readings for measuring the distance travelled, or for voltmeter readings measuring the voltage of the fuel pack, may be included in processor 32.

[056] Location sensor 36 preferably comprises a Global Positioning System (GPS) receiver and a mapping processor. The purpose of location sensor 36 is
30 to determine the position coordinates of the UGV in real time. For the purposes

of this invention, it is understood by an art-skilled person that the use of GPS systems for obtaining the location coordinates of a certain location is part of the state of the art and will therefore not be discussed in detail. Location sensor 36 continuously monitors the position coordinates of the UGV and transmits the position coordinates to base station 10 via wireless transceiver 42 of modular sensing unit 30. Alternatively, location sensor 36 may be programmed to monitor and transmit the position coordinates at fixed intervals, for example, every 5 minutes.

[057] Power supply sensor 34 monitors the power supply level or battery condition of the UGV. This may be the remaining power or voltage in the battery or batteries of the UGV. Power supply sensor 34 continuously monitors the status of the power supply and transmits this information to base station 10. When the remaining power in the battery or batteries of the UGV reaches a predetermined level as set by base station 10, a low fuel or battery alert may be triggered by base station 10, which may activate a set of instructions to the specific UGV concerned. This set of instructions may include returning to base station 10 for refueling, dispatching a UGV fuel tanker to refuel the specific UGV concerned or dispatching a mobile refueling station (MRS) 60 (see Figure 5) to a designated and convenient location for the UGV to refuel. Preferably, for base station 10 to activate the set of instructions, the predetermined level of power remaining in the battery or batteries should be in the range of from about 10% to 20% of the power supply.

[058] In a preferred embodiment, the position coordinates and the power supply data sent by location sensor 36 and power supply sensor 34, respectively, to base station 10 will contain a UGV identification number or a unique number that is associated with each of the UGVs. To differentiate the data being received by base station 10 by each of the plurality of UGVs for processing, the UGV identification number will be sent together with the data for processing to enable base station 10 to identify the specific UGV.

[059] Figure 3 is a flow diagram that illustrates the above described method of optimizing the refueling and resupply of the UGVs. Base station 10 monitors in real time, or at predetermined intervals of time, the precise location and the power supply of each of the plurality of UGVs. As described above, location sensor 36 and power supply sensor 34 transmit this data in the form of position coordinates and the power supply level, respectively, from each of the UGVs to processor 12 of base station 10. If the remaining power supply level of the UGV reaches a predetermined level to trigger a low fuel alert to processor 12, processor 12 will proceed to determine the refueling protocol, that is, the refueling schedule or method.

[060] The refueling schedule or method is stored on data module 14 of processor 12 and is a preprogrammed set of instructions that will be triggered when certain variable or combinations of parameters are reached. The incoming data, for example, the power supply reading and the position reading of each UGV, will be compared with the database of data module 14. The refueling schedule or method is determined based in part on the distance between a specific UGV and the base station. The position coordinates of the UGV are measured relative to the position coordinates of the base station, and the distance between the two is determined and compared with the database of data module 14. If the distance between the UGV and the base station is below a certain predetermined value, processor 12 will subsequently either send instructions to the UGV to return back to base station 10 or dispatch a UGV tanker to the location of the UGV having low fuel to facilitate refueling.

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[061] The predetermined distance value for the activation of a given set of instructions will depend on a number of parameters. These parameters could include the maximum communication range of the UGVs with the base station, the operational requirements of the mission concerned, or whether the UGV has enough power supply to return to base station.

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[062] Preferably, if the distance between a UGV in need of refueling and the base station is above a certain predetermined value, processor 12 of base station 10 will activate the dispatch of mobile refueling station (MRS) 60 to the specific UGV having low fuel. Preferably, for the MRS to be deployed, the predetermined distance between the UGV and the base station is in the range from about 2 to 10 kilometers.

[063] Processor 12 will next determine the optimum location of MRS 60 with respect to the UGV concerned based on the following parameters:

- (a) the power supply level of the UGV concerned;
- (b) the proximity of UGVs in a designated sector; and/or
- (c) mission configuration of the UGV.

[064] The base station 10 will assess the proximity of the other UGVs with respect to the UGV having a low fuel. If there are other UGVs located within the vicinity which are of a predetermined power supply reading and are within a range of from about 2 to about 10 km to the UGV having low fuel, base station 10 will determine the location where the MRS 60 will be dispatched. A predetermined power supply level of the other UGVs may be programmed to be from about 10% to 50% of its power supply level to be considered for assessing its proximity to the UGV having low fuel. In a preferred embodiment of the invention, and notwithstanding the other parameters, base station 10 will determine the optimum location of the MRS to be within a range of from about 1 to about 5 km to the affected UGVs concerned.

[065] Other than proximity and fuel level of the other UGVs with respect to the UGV having low power supply, the mission configuration of the UGV is also considered for determining the optimum location of the MRS. Mission

configurations may be assessed based on the objective of the mission, for example, whether the mission is for defense, reconnaissance or attack. The type of mission configuration will determine if the base station is static or dynamic. For a reconnaissance mission, base station 10 will be mobile and
5 advancing together with the UGVs as long as the sector of interest is secured. However, for a given location of base station 10, the optimum location of the MRS to be dispatched will be determined based on the other parameters, for example, the fuel level and proximity of the other UGVs with respect to the UGV having low power supply.

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[066] In a defense mission, base station 10 is normally static and the UGVs are dispersed in a network formation. Figure 4 illustrates a typical defense related mission where the UGVs are dispersed in a star topology network formation. The UGVs are equally dispersed apart from the base station.
15 Conventionally, the UGVs will be moving to and from the base station for refueling. In a preferred embodiment of the present invention, a plurality of MRS 60s will be dispatched or deployed along the circumference of the defense zone as shown in Figure 4.

20 [067] To deploy an MRS, base station 10 may activate aerial vehicles, for example, helicopters, airplanes or unmanned aerial vehicles (UAV). The position coordinates of the optimum location for deployment of an MRS 60 will be transmitted to the aerial vehicle with the MRS 60 loaded onto the aerial vehicle. Preferably, the aerial vehicle will air drop the MRS 60 or a plurality of
25 MRSs at the intended optimum location. Other means of dispatch are also possible. Once an MRS 60 is in its intended optimum location, the MRS 60 will transmit its actual location coordinates to the base station for update. The mechanism of the MRS 60 will be explained in detail below. The base station, upon receipt of the actual location coordinates of the MRS, will subsequently
30 notify the UGVs concerned of the location coordinates of the MRS. Each affected UGV will subsequently navigate its way to the MRS for refueling.

[068] The advantage of the method described above for optimizing the refueling of UGVs is to save time for the UGVs to travel to and from a base station for refueling. This results in more efficient patrolling when there is a defense situation and reduces or minimizes any possible breaches of the secured area. It also ensures high security readiness of the secured area. For reconnaissance missions, the UGVs may have to travel a further distance to perform surveillance operations. Travelling back to a base station 10 for refueling, especially when the UGV is located far outfield, is time consuming and inefficient since the UGV will have to travel the same distance to return to its previous position in order to move forward.

[069] Figure 5 is a perspective view of a mobile refueling station (MRS) 60. Mobile refueling station 60 is a stand alone, automated refueling station which may be dispatched to the affected UGVs. Mobile refueling station 60 may be air dropped by an airplane, a helicopter or a UAV to a certain predetermined location. Preferably, the predetermined location is in a safe and secure location near the affected UGVs so that the UGVs do not have to travel far to refuel. A mobile refueling station 60 may also be catapulted to the predetermined location by a launching means.

[070] Mobile refueling station 60 includes at least one battery cartridge or pack 61. Battery pack 61 may be in cartridge form to facilitate easy storage and handling by the UGV for refueling. Preferably, battery pack 61 is located on part of the exterior of the station. Each of battery pack 61 is operatively associated with a docking sensor 65. A docking sensor 65 senses the presence of a UGV when it is in the process of refueling and activates the refueling process. The docking sensor is also used for aiding the UGV to align itself to the mobile refueling station during refueling.

[071] To withstand adverse shock upon landing, it is preferable that the outer casing 62 of the MRS 60 is a shock absorbent material.

5 [072] MRS 60 includes a processor 66 for monitoring the battery pack inventory of MRS 60. This information is transmitted via a long range radio transceiver 68 on MRS 60. Processor 66 may include a central processing unit with a modular communication bus rack 64. Modular communication bus rack 64 includes various modules that support processor 66. These modules may include the GPS, radio communication, docking or guidance sensors, and
10 power supply modules. The GPS module receives signals through GPS antenna 63 and determines the position coordinates of the MRS upon landing. This information is transmitted via long range radio transceiver 68 to base station 10.

15 [073] Docking sensors 65 comprise of various different sensors which are also responsible for aligning the UGVs for refueling. Some of these sensors may include ultrasonic, active infrared, and computer vision type sensors. (Please indicate some examples of the various different sensors) This facilitates the docking of the UGV when it is approaching the MRS 60 for refueling. The
20 docking sensors 65 guide the UGV in an appropriate position for the efficient transfer or swapping of the battery packs.

[074] Figure 6 is a side view of the refueling process where an UGV 90 is in position for refueling with respect to an MRS 60. Each UGV 90 includes an
25 opening 72 suitable for the insertion of a battery pack into a power supply compartment 74 of the UGV. As described above, the docking sensors 65 of the MRS will guide the UGV into an appropriate position whereby the battery pack 61 in the MRS may be inserted into opening 72 of the UGV. The docking sensors 65 are actively communicating with the processor of the UGV such that

directional information received from the docking sensors 65 will guide the UGV into moving to the desired docking position.

[075] Once the desired docking position is achieved, docking sensor 65 of the MRS, upon detecting that the UGV is in the right position, will then activate the refueling process. A linear actuator 67 located within the MRS 60 will be activated to shift or move battery pack 61 to a position where battery pack 61 may slide into and through opening 72 of the UGV. The UGV, upon receiving the battery pack from the MRS, will facilitate the movement of the battery pack 61 into a position within the UGV. This may be in the form of a conveyor belt 76 to move battery pack 61 into the desired location.

[076] The desired location for a successful refueling process occurs when an outlet 69 of battery pack 61 is coupled to a power supply inlet 91 of the UGV, as shown in Figure 7. Power supply compartment 74 of the UGV may include a locking mechanism (not shown) which presses battery pack 61 once in the desired location to keep the battery pack in position. The locking mechanism also serves to act as power rails to draw power from the new battery pack. The UGV is now able to draw power from both the old and the new battery pack.

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[077] An option to battery pack 61 in the form of battery cells may be a fuel pack containing liquid fuel. Similarly, a locking mechanism presses the fuel pack into its desired location to keep the fuel pack in position. Once in position, a fuel syringe from the UGV will be inserted into the fuel inlet of the cartridge. The UGV is now able to draw power from both the old and new fuel pack.

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[078] Once the battery or fuel pack is engaged with the UGV, the old battery or fuel pack may be subsequently moved to the end of the conveyor belt and purged out beneath the UGV by gravity. In this manner, the UGV is at all times

powered due to the hot swappable technique of drawing power from the old and new battery or fuel pack before disengaging the almost depleted battery or fuel pack and no down time is experienced.

5 [079] Although the invention has been herein shown and described in what is conceived to be the most practical and preferred embodiment, it is recognized that departures can be made within the scope of the invention, which is not to be limited to the details described herein but is to be accorded the full scope of the appended claims so as to embrace any and all equivalent devices and
10 apparatus.

[080] "Comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features,
15 integers, steps, components or groups thereof.

CLAIMS

1. A system for optimizing the refueling of a plurality of unmanned ground vehicles (UGVs) comprising:

5 a plurality of UGVs, each UGV having a modular sensing unit thereon, the modular sensing unit comprising (a) a power supply sensor, (b) a location sensor, and (c) a transmitter coupled to said power supply sensor and said location sensor, for receiving and transmitting a power supply level and a location of each UGV;

10 a base station having a first receiver for receiving the power supply level and the location of each of the plurality of UGVs, a processor coupled to the receiver for storing the power supply levels and for determining the distance between the base station and the UGV, for each UGV, and a transmitter coupled to said processor; and

15 a mobile refueling station capable of refueling a UGV at a predetermined location, said mobile refueling station having a second receiver for receiving commands from said processor,

wherein the base station processor generates commands for said mobile refueling station based upon a refueling protocol.

20 2. The system of claim 1, wherein the processor in the base station sends a command to deploy the mobile refueling station when the power supply level of one of said plurality of UGVs reaches or is less than a predetermined lower value and the distance between said UGV and the base station is equal to or greater than a predetermined value.

25 3. The system of claim 2, wherein the predetermined lower value of the power supply level of said one UGV is in the range of from about 10% to about 20% of the total power supply of the UGV.

4. The system of claim 2, wherein the predetermined distance between said one UGV and the base station is in the range of from about 2 to about 10 km.
- 5 5. The system according to claim 2, wherein said processor in said base station determines a location to deploy the mobile refueling station based upon the power supply levels of other UGVs within the vicinity of said one UGV.
- 10 6. The system according to claim 5, wherein the power supply levels of other UGVs within the vicinity of said one UGV are each within the range of from about 10 to about 50% of the total power supply of each of the other UGVs.
- 15 7. The system according to claim 2, wherein the base station will activate a refueling tanker to said one UGV when the power supply level of said one UGV reaches a predetermined level and said one UGV is greater than a predetermined distance from the base station.
- 20 8. The system according to claim 7, wherein the base station is mobile.
9. The system according claim 7, wherein the refueling protocol is further determined based on mission configuration of the plurality of UGVs.
- 25 10. The system according to claim 1, wherein the mobile refueling station is sent to a predetermined location by an aerial vehicle.

11. The system according to claim 1, wherein the mobile power refueling station further comprises at least a battery cartridge for recharging the UGV.

5 12. The system according to claim 1, wherein the mobile power refueling station further comprises a global positioning sensor for determining its location data.

10 13. The system according to claim 1, wherein the mobile power refueling station further comprises a communication interface for transmitting location data to the base station.

15 14. The system according to claim 1, wherein the mobile power refueling station further comprises a docking sensor for guiding the UGV to a docking station for recharging the power supply of the UGV.

20 15. The system according to claim 1, wherein the mobile power refueling station further comprises shock absorbing means on the exterior of the refueling station to withstand adverse shocks to the refueling station upon landing on ground.

16. A method for optimizing the refueling at least one of a plurality of unmanned ground vehicles (UGVs) comprising:

obtaining power supply levels of each of the plurality of UGVs;

25 transmitting the power supply levels of each of the plurality of UGVs to a base station;

obtaining locations of each of the plurality of UGVs;

transmitting the locations of each of the plurality of UGVs to the base station; and

determining a refueling protocol for one of said plurality of UGVs based upon the received power supply levels and locations of each of said UGVs.

17. The method according to claim 16, wherein a mobile refueling station for said one UGV is deployed based on the power supply readings and the distances between the UGVs and the base station.

18. The method according to claim 17, further comprising determining the refueling protocol by sending a command to deploy the mobile refueling station when said one UGV reaches a predetermined power supply value and a predetermined distance value between said one UGV and the base station.

19. The method according to claim 16, further comprising determining a location for the mobile refueling station, the location of the mobile refueling station deployed determined being based upon the power supply levels of other UGVs within the vicinity of said one UGV.

20. The method according to claim 19, wherein the predetermined lower value of the power supply level of said one UGV is within the range of from about 10 to about 20% of the power supply of said one UGV.

21. The method according to claim 20, wherein the predetermined distance between said one UGV and the base station is within the range of from about 2 to about 10 km.

22. The method according to claim 21, wherein the power supply reading of the other UGVs within the vicinity of said one UGV is within the range of from about 10 to about 50% of the total power supply of each of the other UGVs.

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23. The method according to claim 22, further comprising deploying a refueling tanker to said one UGV when said one UGV reaches a predetermined power supply reading and outside the range of the predetermined distance between said one UGV and the base station.

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24. The method according to claim 24, wherein the base station is mobile.

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25. The method according claim 24, wherein the refueling schedule is further determined based on mission configuration of the plurality of UGVs.