

Hovering UAV with virtual tethering capability

5 TECHNICAL FIELD

[001] This invention concerns unmanned aerial vehicle (UAV) having hovering capability for purposes of gathering visual data beyond visual range that may be obtained at ground level. The UAV may have navigational features
10 for tracking a moving subject as well as means for image acquisition of the subject and telecommunications link to a ground control.

BACKGROUND ART

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[002] Visual information is critical for most situations, particularly before a certain decision may be made or an action may be taken. In many of these situations, decision or action can only be taken upon visual confirmation. For example, in maritime radar surveillance, long-range radar may be able to watch
20 over a wide swath of territory for intrusions but the detection of an intruding object on the radar screen would only be represented by a blip. Visual inspection of the actual object is always necessary to decide the next course of action such as destroying it, driving it away by force or threat, deploying escort or just leaving it alone.

[003] Apart from the military need for visual confirmation of a subject or target, the need for "beyond visual range" (BVR) capability is also important for local government and other civil organizations such as in crowd control, traffic conditions, news gathering and open air entertainment or sports events. In the surveillance of large crowds – whether an unruly one which may deteriorates into riot or a peaceful rally, security personnel in charge of crowd control will need to know the number of people and their movements through streets and alleys or areas spilled over by the crowd, potential hotspots for stampede, etc. Deploying personnel on tall buildings may provide the necessary visual information but from a static point of view which may become out-dated quickly as the crowd moves on the streets below.

[004] Deploying helicopters is expensive and cannot be sustained for long hours without refueling at an airbase some distance away. The dangers of deploying helicopters to track moving subjects such as commonly practised in live news gathering in the U.S. were shown in the unfortunate incident in Phoenix, Arizona, on 27th July 2007 where 2 news helicopters covering a police chase of a suspect's car crashed in the air, killing all 4 TV reporters on board.

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[005] Apart from law and order needs, access to visual information is also widely craved in many entertainment and sporting activities, such as open air concerts, extreme sports such as mountain climbing, windsurfing, cross-country skiing, or where the competition field is too wide and distant to be followed

under normal ground-level vision such as a car racing circuit, sailing, etc. which are not easily observable or even accessible by spectators. Present practice of installing live camera with a racing car, for example, gives a narrow view from the perspective of the driver and not the overall lead situation. Placing
5 cameras at strategic locations around the circuit requires the central or site station control to frequently switch video feeds between the cameras, still without the advantage of a bird's eye view which is presently provided by airborne cameras such as that on a helicopter.

10 [006] Whilst it is known in the art to equip unmanned aerial vehicles (UAV) in the form of micro-aerial vehicle (MAV) in conjunction with an unmanned surface vehicle (USV) to provide video surveillance such as disclosed in U.S. Patent No. **6,712,312** (U.S. Navy) which transmit the video data by wireless communications, the MAV's known endurance in the air would not be sufficient
15 for extended surveillance such as that required for prolonged event. Besides, there is no disclosure therein on providing a navigation and video lock on a subject being tracked.

[007] On the other hand, there are known devices which are kept airborne by
20 balloons so as to enable tracking and locating of stranded survivors by radar or other reflecting radio wave means such as disclosed in U.S. Patent No. **4,120,259** (Raymond Lee). Once launched, the balloon device is kept tethered to the survivors and naturally there is no disclosure on video feed.

SUMMARY OF DISCLOSURE

[008] It would thus be desirable to have an aerial view of such events from
5 an altitude that would give a spectator or controlling user the desired bird's eye
view of a subject without the dangers and disadvantages of turbulence, down
drafts, noise, relatively short airborne period and high costs associated with
helicopters. It would further be desirable that such aerial machine be
unmanned to save on at least some 70 kg of pilot weight even if it is a single-
10 manned aerial vehicle.

[009] Another desirable feature would be to have the vehicle kept afloat or
airborne with the less drive or passively so that power may be conserved for
directional driving only. With this feature, the airborne time of the vehicle may
15 be greatly prolonged. Still, another feature desired is to have such an aerial
vehicle automatically tracks and moves in the air according to the direction of
movement on the ground of a subject or a user in control of the aerial vehicle.

[010] As a general embodiment of our invention, an unmanned aerial vehicle
20 (UAV) with hovering capability is provided comprising (a) means for
substantially keeping said UAV in a hovering position; (b) directional propulsion
means; (c) image sensing means; and (d) means for transceiving signals
to/from said UAV with respect to a ground control, including (i) sending image
data captured by said image sensing means to said ground control; and (ii)

receiving signals for controlling said directional propulsion means to maintain said UAV in a hovering position relative to a predetermined subject.

[011] In a first aspect of our invention, the means for substantially keeping
5 said UAV in a hovering position comprises a balloon fillable with a gaseous matter lighter than ambient air. Preferably, the gaseous matter is supplied in compressed and/or liquefied, and wherein the release into gaseous form is controlled by valve means. The gaseous matter is preferably a supply of compressed or liquefied helium (He). Alternatively, the gaseous matter is hot
10 air generated by heating ambient air with a heat source on-board. In a specific embodiment, the release into and/or leakage of gaseous matter from the balloon is controlled to achieve any one or combination of a desired or preset altitude, ascend or descend rate.

15 [012] In a second aspect of our invention, the directional propulsion means includes any one or combination of propeller, rudder, drive actuators and control means therefor.

[013] In a third aspect, the image sensing means comprises at least an
20 electro-optical and/or infrared image sensor capable of sensing, capturing and sending image data to ground control, including continuous video streaming data and/or stills capture data by wireless transmission. Preferably, the image sensors include any one or combination of lens zooming, pan and tilt features. Alternatively, the image sensors include any one or combination of infrared,

low-light and hyperspectral image capture for low light and night vision operation. The image sensors are preferably trainable on the predetermined subject from a viewport housed on-board said UAV.

5 [014] In a fourth aspect of the unmanned aerial vehicle according to our invention, the sensing means for assisting in positioning and navigation preferably includes any one or in combination of an altimeter and/or barometer, a GPS decoder, a digital compass, and the like.

10 [015] In a fifth aspect, our UAV may be configured to hover at a predetermined altitude and distance in a virtual tether to a moving ground control. Specifically, it may be configured to hover at a predetermined altitude and distance ahead of a moving ground control. Alternatively, it may be configured to hover at a predetermined altitude and distance lagging behind a
15 moving ground control. Yet, another alternative is to configure it to hover at a predetermine altitude and distance in a virtual tether to a moving ground control upon which the image sensing means are preset to automatically train. Conceptually, our UAV may be said to hover at a predetermined altitude and distance in a virtual tether to a predetermined subject upon which the image
20 sensing means are preset to automatically train.

LIST OF ACCOMPANYING DRAWINGS

[016] To assist in better understanding our invention, we would now refer to the following drawing(s) which accompanies this specification. The drawings
5 will be further described in detail in the following as non-limiting and exemplary illustration of specific or preferred embodiments of our invention, in which:

[017] FIGURE 1 discloses a schematic diagram of the main components and their configuration in a UAV according to our present invention.

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[018] FIGURE 2 illustrates a simplified elevation drawing of a UAV according to our invention embodied as a balloon device.

[019] FIGURE 3 shows two configurations of tracked navigation and
15 surveillance in which the UAV is virtually tethered to a moving user or ground control.

[020] FIGURE 4 shows another configuration of tracked navigation and surveillance in which UAV is virtually tethered to a subject under video
20 surveillance wherein the ground control or user is elsewhere.

[021] FIGURE 5 shows a logic flow diagram of the signal and data transmission and actuation of components of the UAV.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[022] Briefly, the vision capability achieved with our invention extends beyond the normal visual range by using video image gathering means from an elevated position provided by a UAV equipped with optical sensors and the like. 5 The autonomous or semi-autonomous UAV will automatically fly at a designated or preset distance away relative to the user. Captured videos or still images may be wirelessly transmitted back to the user. When the user's position is changed as he or she moves, the UAV will automatically move its 10 airborne position to stay at that relative designated or preset distance away. Thus, the UAV may be preset to follow, or alternatively preset to lead, the user's current position.

[023] Associated with this preset navigation while airborne with reference to 15 a user or to a subject of camera training is "virtual tethering" which means the UAV's position will be automatically changed with respect to the moving user or subject in a virtual tether. Without a real tethering cable or cord, there will thus be no dangers of getting the actual or physical tether entangled with overhead utility cables, bridges, billboards, trees and other interfering structures.

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[024] Cameras on board the UAV may be preset, or dynamically controlled, to train on a subject to capture visuals whether in form of video or stills. The UAV's camera may be configured to look ahead of the user (e.g. at a preset

scope or field of vision at forward terrain ahead of the user leading an advancing military unit) or to look at the user as the subject.

[025] The UAV is expected to be lightweight and compact and can be hand-packed and deployed quickly. Once deployed, they will fly off and stay airborne at a designated distance. For use in crowd control and riot suppression situations, the field commander may choose to deploy several such UAVs at positions and altitudes of his choice to provide bird's eye view from multiple angles for better views on crowd size, hidden elements behind crowd lines and crowd movement. In a vehicle traffic jam, the UAVs may be controlled to fly to trail an elongating jam from a gridlock situation and thus allow traffic controllers to divert fresh traffic from joining up with the tail end of the jam.

[026] When coupled with zoom capabilities, the UAV-mounted cameras may thus provide the vital visual confirmation in real time for action to be taken immediately, or enable video recording of events for review and analysis later, or for purposes of evidence-taking. With such capabilities, helicopter deployment and its associated costs and dangers may be avoided. Deployment of personnel as spotters atop tall buildings for look out purposes may also be avoided and associated dangers such as a spotter trapped by an angry mob, for example, thus saving on valuable manpower resources.

[027] In maritime surveillance operations, several such UAVs may be launched to follow the patrol vessel at a designated distance relative (or

“virtually tethered”) to the patrol vessel. This gives the operation immediate expanded visual field beyond the horizon and thus complementing their radar equipment. Expensive aircraft sorties need not be launched if not necessary, i.e. if only for the purpose of surveillance, unless a military action is to be taken.

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[028] For recreation or sporting purposes, especially the aforementioned extreme sports, these UAVs may be deployed as remote airborne “cameramen” that follows the action at designated distances. These actions may be transmitted back for the spectators to enjoy at a more involved distance. Viewing an extreme mountain climber will now not need to risk another climber with a camera or a helicopter which may generate turbulence or downdraft detrimental to the action or safety of the sportsmen. Getting into the action of windsurfing will now not need real cameramen on boats. Even car racing can now be viewed with a “rear” following view to capture all the best moments and actions. In fact, any situations or activities that require “eyes” to look further, safer and cheaper can now be achieved.

[029] To achieve the aforesaid, the UAV, method and system according to our invention may now be described in detail with reference to the accompanying drawings in the following. The principal components of our invention comprises of a lightweight compact balloon UAV, an autonomous or semi-autonomous navigation systems on board the UAV, video and/or image capturing sensors, including optical sensors on board the UAV, and a datalink system for transmitting the sensor data.

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[030] Alternatively, with or without the navigation systems, image sensors and datalink system with a user serving as ground control, a self-following and homing system for the UAV may be provided either as an independent module
5 or integrated with the overall system according to our present invention.

[031] As proposed, a lightweight compact balloon UAV is used as the main mobile platform. With its compact size, it may be hand-packed and launched quickly and easily, either from ground level or from atop tall buildings. With the
10 appropriate valve controls, the balloon size may be regulated to be filled with the appropriate amount of light gas such as helium and thus the UAV may be airborne at a desirable height for achieving the best angle of sight with the assistance of a small propeller and a rudder. With passive floatation provided by the balloon, the UAV's energy consumption may be brought down to the
15 lowest, thus allowing maximum flight time.

[032] The balloon UAV may typically be deployed to an altitude of about 100 m to 200 m. This allows a good optical pickup of a localized region with significant details. The balloon, with its payload and helium supply providing
20 the lift, can operate in any natural existing temperatures of -40°C to 80°C. Preferably, however, the balloon should be operated in no or low wind conditions, i.e. 0 to 5 knots, so that it's airborne position and navigation is not too much affected and so that its compensating propulsion does not drain too much energy from the UAV power source.

[033] As shown in Figure 1, batteries may provide the source of power supply **1** to all other components and systems that require power in the balloon UAV. Whilst it is shown that each component is supplied with its own power source, this is a schematic or diagrammatic representation only. It would be obvious that as an alternative all these components may be configured to share a common power source from a single battery pack providing the requisite voltage and current.

[034] Optical sensors may be installed to capture and provide a video data stream feed **2** which will be sent to the radio modems or transmitters to be transmitted to a user or ground control. A digital compass may provide digital signal of the UAV's directional heading **3**. An onboard GPS decoder may provide the UAV's current geographical position **4**. With the directional heading **3** and geographical position **4**, user position and desired altitude **7**, a control computer will be able to compute the necessary actuators' parameters **9** and move the drive actuators to maintain position or altitude of the UAV if it has drifted due to wind conditions, or to change or move to a new position as controlled by the user, or automatically changes its airborne position in parallel with a ground subject's movement. Current UAV's directional heading and position **6** may also be sent back via the radio modems or transmitter to the user. The drive actuators will finally move **11** flight surfaces of the balloon UAV to fly to the desired direction and/or position. The drive actuators will also control helium supply valves **10** to inflate the balloon **12** to an optimum volume to raise the balloon UAV to the desired altitude as required by the user.

[035] Autonomous and navigation systems on the UAV are housed on board the UAV. With the autonomous and navigation systems providing the requisite directional and position data as well as in control of the helium supply valves
5 **10**, drive and directional actuators, the UAV can automatically fly, align and navigate itself to any location with reference to the user.

[036] In Figure 2, the helium filled balloon **13** will provide the lift to raise it to a desired altitude. The amount of helium released from the supply (which may be
10 in the form of compressed or liquefied gas) via a valve may be controlled by the control computer. With suspending ropes **14**, the balloon will lift up the payload containing all the components. Helium feed is provided via a valve and pipe **15** from the helium canister to the balloon. A rudder **16** driven by actuators and controlled by the control computer will allow balloon UAV to perform yawing
15 and turning maneuvers when the propeller **18** is providing forward thrust. The propeller **18** can also be actuated to rotate in reverse direction to provide reverse thrust to fly the balloon UAV backwards.

[037] Optical sensor payload on the UAV may preferably contain an electro-
20 optical and/or infrared (EO/IR) sensor system onboard GPS, along with the aforementioned digital compass, radio modems, control computer, drive actuators, batteries and helium supply. The optical sensors will capture videos and images to be transmitted back to the user. Different types of optical sensors can be mounted for different uses. IR and low-light cameras can be

used for night operations. Zoom capabilities can be added for the extra reach. The optical sensors, and lenses if applicable, will be placed within a protective housing with the lenses directed to capture images through a transparent window or viewport **17** in Figure 2 to protect the sensitive devices from the
5 elements.

[038] Advances in the infrared hyperspectral sensing engineering has enabled simplified configuration of devices, such as that disclosed in U.S. Patent No. **7,135,682** (University of Hawaii) which is admitted here not as a
10 prior art but rather as an enabling technology complementing our invention. In this enabling art, wherein a combination of an interferometer with an uncooled micro-bolometer array camera has enabled the capture of hyperspectral images without the use of conventional bulky, power-intensive motorized components, thus making it suitable for small mobile platforms such as a UAV.

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[039] A datalink system for transmitting the sensor data may comprise of wireless communication protocols and data layers to allow both uplink and downlink of data. Downlink communications will be used for transmitting videos and images and other UAV flight information. Uplink communications will be
20 used for transmitting the current location and direction of the user to the UAV for self-following or navigation purposes. This datalink system may be procured as a commercial off-the-shelf (COTS) radio modem product if our UAV components are to be configured or built from digital electronic components. This modem preferably has a data rate of full duplex 30 kbps, and

supports encrypted transmission and operates in the frequency band of 1755 to 1850 MHz, which can be changed to operate in the VHF/UHF or K_u-band frequencies.

5 [040] To facilitate speed and ease of video data transmission, it is preferred that our video imaging capture and transmission on board the UAV be carried out with industrial standard compression and decompression, preferably with MPEG-4 or MPEG-2 codecs.

10 [041] Another preferred wireless transceiving feature of our UAV is to have the capability of communicating via direct line-of-sight (LOS) or beyond-line-of-sight (BLOS) via SATCOM connections where the user or ground control is at a distance far away from the subject and the UAV monitoring that subject, such as in the case of our balloon UAV being deployed to track competing yatches
15 in an open sea sailing competition while the user or ground control is located several kilometers on shore.

[042] Self following and homing system may be illustrated with reference to FIGURE 3 and FIGURE 4 collectively. The Self-following and homing system
20 in the UAV will make use of its own location information, the user's location information, and then computes the new location it shall fly to adhere to the following criteria. Directional data will so be computed depending on what the UAV is configured for – to look ahead, or look at the user.

[043] The control computer retrieves the user heading and location, desired altitude of the balloon UAV, look direction and following distance from the user computer via the radio modems. This information is then used to compute the new location, heading and altitude of the balloon UAV. With current position
5 and heading retrieved from the digital compass and onboard GPS, the control computer will compute actuator parameters to drive the propeller, rudder and/or helium system to maneuver the balloon UAV to the new position. Typical operating range for this balloon UAV will be around 500 m to 1000 m. With the radio modems, the actual communication range may be extended to around
10 6000 m.

[044] FIGURE 5 shows a typical logic flow diagram of the signal and data transmission and actuation of components of the UAV upon which our self-navigating with "virtual tethering" may be implemented with the actuation of the
15 flight controlling elements of the UAV.

[045] It would be obvious to a person having ordinary skill in the art that many of the components, devices, process or logic flow described herein may be modified, altered, varied or substituted with alternatives or equivalents that
20 we have not specifically described here. They are thus not to be considered as departures from our invention but as falling within the scope and spirit of our claims that follows.

CLAIMS

What we claim are:

- 5 1. An unmanned aerial vehicle (UAV) for tracking a dynamic subject comprising:
- (a) means for substantially keeping said UAV in a hovering position;
 - (b) directional propulsion means;
 - (c) image sensing means; and
 - 10 (d) means for transceiving signals to/from said UAV with respect to a ground control, including
 - (i) sending image data captured by said image sensing means to said ground control; and
 - (ii) receiving signals for controlling said directional propulsion means;
- 15 wherein the directional propulsion means comprises drive actuators controlling supply of gaseous matter into the UAV for raising and lowering the UAV to a predetermined height relative to the object tracked and the directional propulsion means configured such that the UAV hovers at a predetermined altitude and distance in a virtual tether to the dynamic subject.
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2. An unmanned aerial vehicle according to claim 1 wherein the directional propulsion means includes any one or combination of propeller, rudder, drive actuators and control means therefor.

3. An unmanned aerial vehicle (UAV) according to Claim 1 wherein the means for substantially keeping said UAV in a hovering position comprises a balloon fillable with a gaseous matter lighter than ambient air.

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4. An unmanned aerial vehicle according to Claim 3 wherein the gaseous matter is supplied in compressed and/or liquefied, and wherein the release into gaseous form is controlled by valve means.

10 5. An unmanned aerial vehicle according to Claim 3 wherein the gaseous matter is a supply of compressed or liquefied helium (He).

6. An unmanned aerial vehicle according to Claim 3 wherein the gaseous matter is hot air generated by heating ambient air with a heat source on-board.

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7. An unmanned aerial vehicle according to any one of Claims 4 – 6 wherein the release into and/or leakage of gaseous matter from the balloon is controlled to achieve any one or combination of a desired or preset altitude, ascend or descend rate.

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8. An unmanned aerial vehicle according to Claim 1 wherein the image sensing means comprises at least an electro-optical and/or infrared image sensor capable of sensing, capturing and sending image data to ground control, including continuous video streaming data and/or stills capture data by

wireless transmission.

9. An unmanned aerial vehicle according to Claim 8 wherein image sensors include any one or combination of lens zooming, pan and tilt features.

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10. An unmanned aerial vehicle according to Claim 8 wherein the image sensors include any one or combination of infrared, low-light and hyperspectral image capture for low light and night vision operation.

10 11. An unmanned aerial vehicle according to Claim 9 wherein the image sensors are trainable on the predetermined subject from a viewport housed on-board said UAV.

12. An unmanned aerial vehicle according to Claim 1 further including
15 sensing means for assisting in positioning and navigation, including any one or in combination of an altimeter and/or barometer, a GPS decoder, a digital compass, and the like.

13. An unmanned aerial vehicle according to Claim 1 configured to hover at
20 a predetermined altitude and distance in a virtual tether to a moving ground control.

14. An unmanned aerial vehicle according to Claim 13 configured to hover at a predetermined altitude and distance ahead of a moving ground control.

15. An unmanned aerial vehicle according to Claim 13 configured to hover at a predetermined altitude and distance lagging behind a moving ground control.

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16. An unmanned aerial vehicle according to Claim 13 configured to hover at a predetermine altitude and distance in a virtual tether to a moving ground control upon which the image sensing means are preset to automatically train.

10 17. An unmanned aerial vehicle according to Claim 1 configured to hover at a predetermined altitude and distance in a virtual tether to a predetermined subject upon which the image sensing means are preset to automatically train.

18. An unmanned aerial vehicle according to Claim 1, further comprising a
15 telecommunications system including audio, video and control data streaming capable of being recorded.

19. An unmanned aerial vehicle according to Claim 1, further comprising a telecommunications system including audio and video data streaming capable
20 of being fed to a live broadcast.

20. An unmanned aerial vehicle according to Claim 1, further comprising a wireless broadcast system.