SUMMARY

[0003a] According to a first aspect of the present invention, there is provided a system comprising:

an aerial vehicle;

a sensor coupled to the aerial vehicle;

a winch system coupled to the aerial vehicle, wherein the winch system comprises a tether disposed on a spool, a motor operable to apply a torque to the tether, and a payload coupling apparatus coupled to a leading end of the tether and configured to mechanically couple to a payload;

a repositioning apparatus mounted on the payload coupling apparatus and configured to reposition the payload coupling apparatus in at least a horizontal direction by applying at least a horizontal force directly to the payload coupling apparatus; and

a control system comprising a processor and a non-transitory computer readable medium having stored thereon instructions that, when executed by the processor, cause the processor to perform operations comprising:

identifying the payload to be picked up by the aerial vehicle within an environment;

controlling the aerial vehicle to hover above the payload;

controlling the winch system to deploy the payload coupling apparatus by unwinding the tether from the spool;

receiving, while the aerial vehicle hovers above the payload and from the sensor, sensor data indicative of a position of the payload coupling apparatus in relation to the payload; and

while the aerial vehicle hovers above the payload, repositioning, using the repositioning apparatus and based on the sensor data, the payload coupling apparatus in the horizontal direction to mechanically couple to the payload.

[0003b] According to a second aspect of the present invention, there is provided a method comprising:

identifying, by a control system, a payload to be picked up by an aerial vehicle within an environment, wherein a winch system is coupled to the aerial vehicle, wherein the winch system comprises a tether disposed on a spool, a motor operable to apply a torque to the tether, and a payload coupling apparatus coupled to a leading end of the tether and configured to mechanically couple to the payload;

controlling, by the control system, the aerial vehicle to hover above the payload;

controlling, by the control system, the winch system to deploy the payload coupling apparatus by unwinding the tether from the spool;

receiving, by the control system, while the aerial vehicle hovers above the payload, from a sensor on the aerial vehicle, sensor data indicative of a position of the payload coupling apparatus in relation to the payload; and

while the aerial vehicle hovers above the payload, providing instructions, based on the sensor data and by the control system, to reposition, using a repositioning apparatus mounted on the payload coupling apparatus and configured to reposition the payload coupling apparatus in at least a horizontal direction by applying at least a horizontal force directly to the payload coupling apparatus, the payload coupling apparatus in the horizontal direction to mechanically couple to the payload.

[0003c] According to a third aspect of the present invention, there is provided a non-transitory computer readable storage medium having stored thereon instructions that, when executed by a computing device, cause the computing device to perform operations comprising:

identifying a payload to be picked up by an aerial vehicle within an environment, wherein a winch system is coupled to the aerial vehicle, wherein the winch system comprises a tether disposed on a spool, a motor operable to apply a torque to the tether, and a payload coupling apparatus coupled to a leading end of the tether and configured to mechanically couple to the payload;

controlling the aerial vehicle to hover above the payload;

controlling the winch system to deploy the payload coupling apparatus by unwinding the tether from the spool;

receiving, while the aerial vehicle hovers above the payload, from a sensor on the aerial vehicle, sensor data indicative of a position of the payload coupling apparatus in relation to the payload; and

while the aerial vehicle hovers above the payload, providing instructions based on the sensor data to reposition, using a repositioning apparatus mounted on the payload coupling apparatus and configured to reposition the payload coupling apparatus in at least a horizontal direction by applying at least a horizontal force directly to the payload coupling apparatus, the payload coupling apparatus in the horizontal direction to mechanically couple to the payload.

[0004] In an example embodiment, an unmanned aerial vehicle (UAV) may be configured to pick-up, transport, and drop-off payloads. The UAV may include a winch system having a tether disposed on a spool, driven by a motor, and configured to deploy a payload coupling apparatus coupled to the tether so as to engage a payload before pick-up or disengage the payload before drop-off. When picking up a payload, a control system of the UAV may,

using one or more sensors coupled thereto, identify the payload within the environment and deploy the payload coupling apparatus by unwinding the tether from the spool. The UAV may be repositioned in coordination with the winch system so as to bring the payload coupling apparatus to within a threshold distance of the payload. The position of the UAV may then be fixed above the payload so as not to have movement of the UAV induce oscillations or other movements in the payload coupling apparatus hanging therebelow on the tether.

[0005] A repositioning device or apparatus may be used to reposition the payload coupling apparatus in at least a horizontal direction to mechanically couple the payload to the tether using the payload coupling apparatus. A distance between the repositioning device and the payload coupling apparatus may be smaller than a distance between the UAV and the payload coupling apparatus. Thus, the repositioning device may offer more direct control over the payload coupling apparatus, allowing the payload to be mechanically coupled to the tether faster, with fewer oscillations or unwanted movements of the payload coupling apparatus. The repositioning device may be controlled in coordination with the winch system to simultaneously control both the horizontal and vertical position of the payload coupling apparatus.

[0006] In a first embodiment, a system is provided that includes an aerial vehicle, a sensor coupled to the aerial vehicle, and a winch system coupled to the aerial vehicle. The

CLAIMS

What is claimed is:

1. A system comprising:

an aerial vehicle;

a sensor coupled to the aerial vehicle;

a winch system coupled to the aerial vehicle, wherein the winch system comprises a tether disposed on a spool, a motor operable to apply a torque to the tether, and a payload coupling apparatus coupled to a leading end of the tether and configured to mechanically couple to a payload;

a repositioning apparatus mounted on the payload coupling apparatus and configured to reposition the payload coupling apparatus in at least a horizontal direction by applying at least a horizontal force directly to the payload coupling apparatus; and

a control system comprising a processor and a non-transitory computer readable medium having stored thereon instructions that, when executed by the processor, cause the processor to perform operations comprising:

identifying the payload to be picked up by the aerial vehicle within an environment;

controlling the aerial vehicle to hover above the payload;

controlling the winch system to deploy the payload coupling apparatus by unwinding the tether from the spool;

receiving, while the aerial vehicle hovers above the payload and from the sensor, sensor data indicative of a position of the payload coupling apparatus in relation to the payload; and

while the aerial vehicle hovers above the payload, repositioning, using the repositioning apparatus and based on the sensor data, the payload coupling apparatus in the horizontal direction to mechanically couple to the payload.

2. The system of claim 1, wherein controlling the aerial vehicle to hover above the payload and controlling the winch system to deploy the payload coupling apparatus comprises:

controlling the position of the aerial vehicle in coordination with the winch system to maneuver the payload coupling apparatus to within a threshold distance of the payload; and

based on the payload coupling apparatus being maneuvered to within the threshold distance of the payload, causing the aerial vehicle to hover in a fixed location above the payload to maintain the payload coupling apparatus within the threshold distance of the payload.

3. The system of claim 1, wherein the operations further comprise:

determining a trajectory for the payload coupling apparatus to follow to mechanically couple to the payload, wherein the trajectory is defined in at least the horizontal direction, and wherein an end of the trajectory coincides with an attachment point for the payload coupling apparatus on the payload; and

actuating the repositioning apparatus to reposition the payload coupling apparatus according to the trajectory.

4. The system of claim 3, wherein the operations further comprise:

suppressing oscillation of the payload coupling apparatus as the payload coupling apparatus approaches the end of the trajectory to reduce a difference between a position indicated by the trajectory and an actual position of the payload coupling apparatus.

5. The system of claim 3, wherein the trajectory defines an orientation of the payload coupling

apparatus relative to the attachment point on the payload, and wherein the orientation of the payload coupling apparatus at the end of the trajectory matches an orientation of the attachment point on the payload to mate the payload coupling apparatus with the attachment point.

6. The system of claim 1, wherein the repositioning apparatus comprises wheels coupled to the payload coupling apparatus and driven by additional corresponding motors, and wherein controlling the aerial vehicle to hover above the payload and controlling the winch system to deploy the payload coupling apparatus comprises:

controlling the position of the aerial vehicle in coordination with the winch system to deposit the payload coupling apparatus and the wheels thereof onto a surface in the environment near the payload.

7. The system of claim 6, wherein repositioning the payload coupling apparatus in the horizontal direction to mechanically couple to the payload comprises:

identifying, based on the sensor data, an attachment point on the payload to which to mechanically couple the payload coupling apparatus; and

causing the additional corresponding motors to drive the wheels over the surface and towards the attachment point to mechanically couple the payload using the payload coupling apparatus.

8. The system of claim 6, wherein the wheels comprise two wheels, and wherein the operations further comprise:

while the aerial vehicle hovers above the payload, controlling the motor of the winch system to maintain tension on the tether while the payload coupling apparatus is repositioned in the horizontal direction to maintain the payload coupling apparatus upright on the two wheels.

9. The system of claim 6, wherein the wheels comprise two wheels, wherein the payload coupling apparatus includes one or more gyroscopes coupled thereto, and wherein the operations further comprise:

receiving, from the one or more gyroscopes, data indicative of a tilt of the payload coupling apparatus; and

based on the data indicative of the tilt of the payload coupling apparatus, actuating one or more of the additional corresponding motors to maintain the payload coupling apparatus upright on the two wheels.

10. The system of claim 1, wherein the repositioning apparatus comprises a plurality of adjustable aerodynamic features on the payload coupling apparatus, and wherein repositioning the payload coupling apparatus in the horizontal direction comprises:

adjusting the adjustable aerodynamic features on the payload coupling apparatus to generate on the payload coupling apparatus, using a downwash of air generated by the aerial vehicle while hovering above the payload, the horizontal force to reposition the payload coupling apparatus in the horizontal direction.

11. The system of claim 1, wherein the payload coupling apparatus includes thereon a plurality of passive aerodynamic features configured to dampen oscillations of the payload coupling apparatus using a downwash of air generated by the aerial vehicle while hovering above the payload.

12. The system of claim 1, wherein the repositioning apparatus comprises one or more thrusters on the payload coupling apparatus configured to push the payload coupling apparatus in one or

more directions, and wherein repositioning the payload coupling apparatus in the horizontal direction comprises:

actuating the one or more thrusters to reposition the payload coupling apparatus in the horizontal direction.

13. The system of claim 1, further comprising:

an actuated arm connected at a first end thereof to the aerial vehicle, wherein the actuated arm comprises at a second end thereof a tether guide through which the tether extends, and wherein repositioning the payload coupling apparatus in the horizontal direction further comprises actuating the actuated arm to push the tether and the payload coupling apparatus in the horizontal direction.

14. The system of claim 1, wherein the system further comprises an arm connected at a first end thereof to the aerial vehicle, wherein the arm comprises at a second end thereof a tether guide through which the tether extends, and wherein the arm is configured to dampen oscillations of the payload coupling apparatus while the aerial vehicle hovers in a fixed location above the payload.

15. The system of claim 1, wherein the sensor is disposed on the payload coupling apparatus and coupled to the aerial vehicle by way of the winch system.

16. The system of claim 1, wherein controlling the aerial vehicle to hover above the payload and controlling the winch system to deploy the payload coupling apparatus comprises:

determining, based on the sensor data, synchronized adjustments to (i) a vertical position of the aerial vehicle, (ii) a horizontal position of the aerial vehicle, and (iii) an extent to which the tether is unwound from the spool; and

adjusting a position of the aerial vehicle in coordination with the winch system to perform the synchronized adjustments.

17. The system of claim 16, wherein the operations further comprise:

determining, based on a length by which the tether has been unwound from the spool, a delay between adjustments in a position of the aerial vehicle and corresponding changes in a position of the payload coupling apparatus; and

adjusting the position of the aerial vehicle in coordination with the winch system based on the determined delay.

18. The system of claim 1, wherein the operations further comprise:

after mechanically coupling to the payload, controlling the aerial vehicle in coordination with the winch system to pick up the payload.

19. A method comprising:

identifying, by a control system, a payload to be picked up by an aerial vehicle within an environment, wherein a winch system is coupled to the aerial vehicle, wherein the winch system comprises a tether disposed on a spool, a motor operable to apply a torque to the tether, and a payload coupling apparatus coupled to a leading end of the tether and configured to mechanically couple to the payload;

controlling, by the control system, the aerial vehicle to hover above the payload;

controlling, by the control system, the winch system to deploy the payload coupling apparatus by unwinding the tether from the spool;

receiving, by the control system, while the aerial vehicle hovers above the payload, from a sensor on the aerial vehicle, sensor data indicative of a position of the payload coupling apparatus in relation to the payload; and

while the aerial vehicle hovers above the payload, providing instructions, based on the sensor data and by the control system, to reposition, using a repositioning apparatus mounted on the payload coupling apparatus and configured to reposition the payload coupling apparatus in at least a horizontal direction by applying at least a horizontal force directly to the payload coupling apparatus, the payload coupling apparatus in the horizontal direction to mechanically couple to the payload.

20. A non-transitory computer readable storage medium having stored thereon instructions that, when executed by a computing device, cause the computing device to perform operations comprising:

identifying a payload to be picked up by an aerial vehicle within an environment, wherein a winch system is coupled to the aerial vehicle, wherein the winch system comprises a tether disposed on a spool, a motor operable to apply a torque to the tether, and a payload coupling apparatus coupled to a leading end of the tether and configured to mechanically couple to the payload;

controlling the aerial vehicle to hover above the payload;

controlling the winch system to deploy the payload coupling apparatus by unwinding the tether from the spool;

receiving, while the aerial vehicle hovers above the payload, from a sensor on the aerial vehicle, sensor data indicative of a position of the payload coupling apparatus in relation to the payload; and

while the aerial vehicle hovers above the payload, providing instructions based on the sensor data to reposition, using a repositioning apparatus mounted on the payload coupling apparatus and configured to reposition the payload coupling apparatus in at least a horizontal direction by applying at least a horizontal force directly to the payload coupling apparatus, the payload coupling apparatus in the horizontal direction to mechanically couple to the payload.