ADHOC GEO-FIDUCIAL MATS FOR LANDING UAVS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The application is based on U.S. Patent Application No. 16/818,799, filed March 13, 2020, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD

[0002] This disclosure relates generally to unmanned aerial vehicles (UAVs), and in particular but not exclusively, relates to visual navigation and landing pads for UAVs.

BACKGROUND INFORMATION

[0003] A UAV is a vehicle capable of air travel without a physically-present human operator. UAVs may be provisioned to perform various different missions, including payload delivery, exploration/reconnaissance, imaging, public safety, surveillance, or otherwise. The mission definition will often dictate a type of specialized equipment and/or configuration of the unmanned vehicle.

[0004] Safe and efficient UAV navigation relies upon the UAV having an accurate and precise navigation solution (for example, a latitude, longitude, and altitude). For example, a UAV may rely on a global positioning system (GPS) to generate a navigation solution in wide open environments; however, GPS navigation may lack the precision necessary to navigate a UAV in confined or crowded environments (such as an indoor UAV base having numerous UAVs). In addition, weather and other contingencies may degrade GPS signal strength, which may compromise the ability of a UAV to generate an accurate navigation solution by GPS. Some environments may experience degraded GPS performance, for example due to multipath, and others may be completely GPS-denied, i.e., may lack GPS signal altogether. These are merely exemplary scenarios, as other challenges characterize UAV navigation. Ultimately, the ability to generate a reliable, accurate, and precise navigation solution is important to efficient and safe UAV navigation.

SUMMARY OF INVENTION

[0004a] According to a first aspect of the present invention, there is provided an apparatus for visual navigation of an unmanned aerial vehicle (UAV), the apparatus comprising:

a geo-fiducial mat including:

a landing pad region that provides a location for aligning with a landing pad of the UAV; and

a survey point indicated on the geo-fiducial mat; and

a plurality of geo-fiducials disposed in or about the landing pad region and each specified for a unique directional and offset position relative to the survey point, wherein the geo-fiducials each includes a two-dimensional (2D) pattern that visually conveys an alphanumerical code, wherein the 2D pattern has a shape from which an optical navigation system of the UAV can visually triangulate a position of the UAV.

[0004b] According to a second aspect of the present invention, there is provided a system for navigating an unmanned aerial vehicle (UAV) during landing or takeoff, the system comprising:

a charging pad for charging the UAV;

a geo-fiducial mat including:

a landing pad region that provides a location for aligning the charging pad with the geo-fiducial mat; and

a survey point indicated on the geo-fiducial mat; and

a plurality of geo-fiducials disposed in or about the charging pad region and each specified for a unique directional and offset position relative to the survey point, wherein the geo-fiducials each includes a two-dimensional (2D) pattern that visually conveys an alphanumerical code different from each other, wherein the 2D pattern has a shape from which an optical navigation system of the UAV can visually triangulate a position of the UAV.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Non-limiting and non-exhaustive embodiments of the invention are described with reference to the following figures, wherein like reference numerals

black, then geo-fiducial mat 110 may generally be colored with a grey scale value of approximately 50.

[0022] In the illustrated embodiment, geo-fiducials are provided in three different sizes small (xx0 – xx3), medium (xx4 – xx7), and large (xx8 and xx9). The illustrated geo-fiducials are positioned at four different corners or along four different sides of landing pad region 211. In one embodiment, the small geo-fiducials are approximately 16.3 cm square in size and positioned closest to the center of landing pad region 211. Of course, other sizes (e.g., 24.3 cm square) may be implemented. In the illustrated embodiment, the small geo-fiducials are adhered to or otherwise disposed on landing pad 9xx in its four corners. In other embodiments, the small geo-fiducials may be centered along the four sides of landing pad 9xx or even positioned on or integrated into geo-fiducial mat 110 immediately adjacent to landing pad 9xx as opposed to being disposed on landing pad 9xx. Due to their closest proximity to the center of landing pad region 211 and their small size, the small geo-fiducials are the first geo-fiducials seen by UAV 105 upon initial takeoff and the geo-fiducials used for navigation at close in distances. They provide close-in navigation for precise landing on landing pad 9xx.

[0023] The medium geo-fiducials xx4-xx7 are larger than the small geo-fiducials and positioned further away from the center of landing pad region 211 than the small geo-fiducials. In one embodiment, the medium geo-fiducials are approximately 32.6 cm square in size. Of course, other sizes (e.g., 48.6 cm square) may be implemented. In the illustrated embodiment, four medium geo-fiducials are each aligned with the mid-point of a corresponding side of the rectangular landing pad region 211. The medium geo-fiducials provide intermediate range navigation to UAV 105 and can be seen by the optical navigation system of UAV 105 from relative higher altitudes than the small geo-fiducials.

[0024] The large geo-fiducials xx8-xx9 are larger than the small and medium geo-fiducials and positioned further away from the center of landing pad region 211 than the small and medium geo-fiducials. In one embodiment, the large geo-fiducials are approximately 81.8 cm square in size. Of course, other sizes (e.g., 122 cm square) may be implemented. In the illustrated embodiment, two ~~medium~~ large geo-fiducials are positioned on opposing sides of landing pad region 211 and aligned with a mid-point of the sides of the rectangular landing pad region 211. The large

CLAIMS

What is claimed is:

1. An apparatus for visual navigation of an unmanned aerial vehicle (UAV), the apparatus comprising:

a geo-fiducial mat including:

a landing pad region that provides a location for aligning with a landing pad of the UAV; and

a survey point indicated on the geo-fiducial mat; and

a plurality of geo-fiducials disposed in or about the landing pad region and each specified for a unique directional and offset position relative to the survey point, wherein the geo-fiducials each includes a two-dimensional (2D) pattern that visually conveys an alphanumerical code, wherein the 2D pattern has a shape from which an optical navigation system of the UAV can visually triangulate a position of the UAV.

2. The apparatus of claim 1, wherein the geo-fiducials comprise at least three geo-fiducials that each convey a different alphanumerical code and are disposed at three different corners or along three different sides of the landing pad region.

3. The apparatus of claim 1, wherein the geo-fiducials comprise:

first geo-fiducials having a first size that are configured to be disposed on or attached to the landing pad.

4. The apparatus of claim 3, wherein the geo-fiducials further comprise:

second geo-fiducials having a second size, larger than the first size, the second geo-fiducials positioned further from a center of the landing pad region than the first geo-fiducials.

5. The apparatus of claim 4, wherein the geo-fiducials further comprise:

third geo-fiducials having a third size, larger than the first and second sizes, the third geo-fiducials positioned further from the center of the landing pad region than the first and second geo-fiducials.

6. The apparatus of claim 4, wherein the landing pad region comprises a rectangular shaped region, wherein the first geo-fiducials are disposed proximate to corners of the landing pad region, and wherein the second geo-fiducials are substantially centered along sides of the landing pad region.

7. The apparatus of claim 4, wherein the second geo-fiducials are integrated into the geo-fiducial mat while the first geo-fiducials are configured to be physically distinct and separate from the geo-fiducial mat for adhering to or otherwise disposing on the landing pad of the UAV.

8. The apparatus of claim 1, wherein the geo-fiducial mat further includes:

a directional marker disposed on the geo-fiducial mat for aligning the geo-fiducial mat with a predetermined direction such that positions of the geo-fiducials are determinable based upon location information of the survey point and the unique directional and offset position specified for each of the geo-fiducials.

9. The apparatus of claim 1, wherein the geo-fiducial mat further includes:

alignment markings disposed on the geo-fiducial mat for indicating the landing pad region and aiding alignment of the landing pad to the landing pad region.

10. The apparatus of claim 1, wherein the alphanumerical code conveyed by each of the geo-fiducials shares a common first portion that is associated with a pad identification of the landing pad and a different second portion that individually distinguishes each of the geo-fiducials of the geo-fiducial mat from each other.

11. The apparatus of claim 10, wherein the pad identification includes:

a first segment having a value indicating that the geo-fiducials are not individually surveyed, but rather locations of the geo-fiducials are computable based at least in part upon location information of the survey point; and

a second segment that matches the common first portion of the alphanumerical code of each of the geo-fiducials.

12. The apparatus of claim 1, wherein the geo-fiducial mat comprises a flexible substrate material that is amenable to rolling or folding.

13. The apparatus of claim 1, wherein the geo-fiducial mat comprises puzzle sections that are separable.

14. A system for navigating an unmanned aerial vehicle (UAV) during landing or takeoff, the system comprising:

a charging pad for charging the UAV;

a geo-fiducial mat including:

a landing pad region that provides a location for aligning the charging pad with the geo-fiducial mat; and

a survey point indicated on the geo-fiducial mat; and

a plurality of geo-fiducials disposed in or about the charging pad region and each specified for a unique directional and offset position relative to the survey point, wherein the geo-fiducials each includes a two-dimensional (2D) pattern that visually conveys an alphanumerical code different from each other, wherein the 2D pattern has a shape from which an optical navigation system of the UAV can visually triangulate a position of the UAV.

15. The system of claim 14, wherein the geo-fiducials comprise:

first geo-fiducials having a first size that are configured to be disposed on or attached to the charging pad.

16. The system of claim 14, wherein the geo-fiducials comprise:

first geo-fiducials having a first size;

second geo-fiducials having a second size, larger than the first size, the second geo-fiducials positioned further from a center of the landing pad region than the first geo-fiducials; and

third geo-fiducials having a third size, larger than the first and second sizes, the third geo-fiducials positioned further from the center of the landing pad region than the first and second geo-fiducials.

17. The system of claim 16, wherein the landing pad region comprises a rectangular shaped region, wherein the first geo-fiducials are disposed proximate to corners of the landing pad region, and wherein the second and third geo-fiducials are substantially centered along sides of the landing pad region.

18. The system of claim 16, wherein the second and third geo-fiducials are integrated into the geo-fiducial mat while the first geo-fiducials are configured to be physically distinct and separate from the geo-fiducial mat for adhering to or otherwise disposing on the charging pad of the UAV.

19. The system of claim 14, wherein the geo-fiducial mat further includes:

a directional marker disposed on the geo-fiducial mat for aligning the geo-fiducial mat with a predetermined direction such that positions of the geo-fiducials are determinable based upon location information of the survey point and the unique directional and offset position specified for each of the geo-fiducials; and

alignment markings disposed on the geo-fiducial mat for indicating the landing pad region and aiding alignment of the charging pad to the landing pad region.

20. The system of claim 14, wherein the alphanumerical code conveyed by each of the geo-fiducials shares a common first portion that is associated with a pad identification of the landing pad and a different second portion that individually distinguishes each of the geo-fiducials of the geo-fiducial mat from each other.

21. The system of claim 20, further comprising the UAV, wherein the UAV includes a controller coupled to memory storing instructions that when executed by the controller cause the UAV to perform operations comprising:

identifying a first segment of the pad identification as indicating that the charging pad has multiple geo-fiducials associated with the charging pad that are not individually surveyed;

computing locations for the geo-fiducials based at least in part upon location information of the survey point received by the UAV and the unique directional and offset position specified for each of the geo-fiducials; and

populating a geo-fiducial map stored within the UAV with the locations for the geo-fiducials.

22. The system of claim 14, further comprising the UAV, wherein the UAV includes a controller coupled to memory storing instructions that when executed by the controller cause the UAV to perform operations comprising:

flying the UAV to a takeoff way point above the geo-fiducial mat;

visually triangulating the position of the UAV with the optical navigation system based upon one or more of the geo-fiducials; and

validating correct operation of a global positioning system (GPS) sensor at the takeoff waypoint based upon the position that is visually triangulated.