

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; 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 alphanumeric 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 alphanumeric 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 alphanumeric 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 alphanumeric 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; 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 alphanumeric 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 alphanumeric 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.