Claims

What is claimed is:

1. A method of determining a force exerted by at least one object onto a surface under the at least one object using at least one optical fiber located below or adjacent to the surface, the method including:

measuring distributed fiber-optic sensing (DFOS) data arising from strain in the at least one optical fiber responsive to the force;

determining at least one relationship between the measured DFOS data and the force; and

processing the measured DFOS data and the at least one relationship to determine the force.

2. The method of claim 1, wherein determining the force includes determining a force distribution including magnitude and location of the force, the method further including deriving object information of the at least one object based on the force distribution.

3. The method of claim 2, wherein the object information includes at least one of: a footprint area of the at least one object, a mass distribution of the at least one object, a velocity of the at least one object, an acceleration of the at least one object, a momentum of the at least one object, a speed of the at least one object, an identity of the at least one object, and a travelling direction of the at least one object.

4. The method of any one of claims 1-3, wherein the at least one relationship between the measured DFOS data and the force is determined by training a machine learning network using at least one of DFOS data and the physical relationship between DFOS measurements and force distribution.

5. The method of any one of claims 1-3, wherein the at least one relationship between the measured DFOS data and the force corresponds to at least one transfer function of a medium between at least one location on the surface and at least one sensing segment on the at least one optical fiber.

6. The method of claim 5, wherein the at least one location on the surface includes multiple locations corresponding to a mesh or matrix of nodes on the surface, and wherein the DFOS data and the at least one transfer function are used to determine the force distribution at specific locations within the mesh of nodes over the at least one sensing segment on the at least one optical fiber.

7. The method of claim 5, wherein determining the force distribution includes using at least one statistical optimization method and inverting a matrix related to the at least one transfer function, wherein inverting the matrix related to the at least one transfer function is performed before performing DFOS.

8. The method of claim 7, wherein the at least one statistical optimization method is conducted in real-time while performing DFOS.

9. The method of any one of claims 5-8, wherein determining the at least one transfer function of the medium between at least one location on the surface and at least one sensing segment on the at least one optical fiber is based on at least two of the material(s) of the medium, the geometry of the at least one optical fiber relative to the at least one location on the surface, and local geological information.

10. The method of any one of claims 5-9, further including selecting at least one gauge length of the at least one optical fiber for performing DFOS, the gauge length corresponding to the at least one segment on the at least one optical fiber.

11. The method of any one of claims 1-10, wherein the at least one object includes a vehicle, and wherein the at least one object information includes at least one of: a count of axles of the vehicle and occupancy of the vehicle.

12. The method of any one of claims 1-11, wherein the surface includes multiple lanes, and the method further includes determining lane quantization of the multiple lanes.

13. The method of any one of claims 11-12, wherein the at least one object comprises multiple vehicles and the at least one object information includes calculating a distance between the multiple vehicles in the X direction and/or in the Y direction.

14. The method according to any one of the preceding claims, further comprising:

generating an alert in response to the calculating of the force.

15. A system for performing DFOS, comprising:

a device configured to emit a laser light into an optical cable and to receive light transmitted by the optical cable; and

one or more processors configured to perform any of the method recited in any one of claims 1-14.

16. A DFOS instrument, comprising:

a light source;

a modulator configured to modulate light generated by the light source;

a photoreceiver;

a controller configured to control at least the light source and the photoreceiver, wherein

the controller is configured to perform a method of any one of claims 1-14.