Claim

1. A method for identifying a foreign object on a runway based on a thermal object image of the foreign object, the method comprising

capturing a thermal image of an area of interest on the runway,

capturing a visible light image of the area of interest on the runway,

detecting a thermal object image in the thermal image, detecting a visible light object image in the visible light image,

determining that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively,

identifying and categorizing the visible light object image into an object category of the foreign object,

determining a relationship between the object category of the foreign object in the visible light image and the temperature of the foreign object in the thermal object image of the foreign object, wherein when a thermal object image of the foreign object is detected, the foreign object is identified by mapping the object category to the temperature of the foreign object in the thermal object image based on the relationship.

2. The method according to claim 1, wherein determining the foreign object comprises generating at least one attribute of the foreign object in each of the thermal object image and visible light object image, comparing the at least one attribute of the foreign object in the thermal object image and the visible light object image, wherein the foreign object is detected when the at least one attribute of the foreign object in thermal object image and the visible light object image are the same.

3. The method according to claim 2, wherein the at least one attribute of the foreign object comprises the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image.

4. The method according to claim 3, wherein the at least one attribute of the foreign object in thermal object image and the visible light object image are the same when the distance

between the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image is within a position parameter.

5. The method according to any one of claims 2 to 4, wherein the at least one attribute of the foreign object comprises the size of the thermal object image and visible light object image.

6. The method according to claim 5, wherein the at least one attribute of the foreign object in the thermal object image and visible light object image are the same when the difference in the size of the thermal object image in the thermal image and the size of the visible light object image in the visible light image is within a size parameter.

7. The method according to any one of claims 1 to 6, further comprising obtaining an enlarged thermal object image and an enlarged visible light object image when the foreign object is detected.

8. The method according to any one of claims 1 to 7, further comprising identifying an object category of the foreign object in the thermal image, wherein identifying the object category comprises,

segmenting the thermal image into a plurality of thermal image regions,

assigning a feature vector to each of the plurality of thermal image regions,

comparing the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category,

identifying the reference feature vector closest to the feature vector and its object category.

9. The method according to claim 8, wherein segmenting the thermal image comprises labelling each pixel in the thermal image and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions.

10. The method according to any one of claims 1 to 9, wherein identifying the object category of the foreign object in the visible light object image comprises,

segmenting the visible light image into a plurality of visible light image regions,

assigning a feature vector to each of the plurality of visible light image regions,

comparing the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category, and

identifying the reference feature vector closest to the feature vector and its object category.

11. The method according to claim 10, wherein segmenting the visible light image comprises labelling each pixel in the visible light image and grouping the labelled pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions.

12. The method according to claim 10 or 11, further comprising training the thermal camera to detect the foreign object based on the visible light images from the visible light camera.

13. The method according to any one of claims 1 to 12, further comprising generating a thermal profile model of the foreign object based on the relationship and optimizing the detection configuration parameters of the thermal camera based on the thermal profile model.

14. A detection system for identifying a foreign object on a runway based on a thermal object image of the foreign object, the system comprising:

a thermal camera comprising a first field of view and adapted to capture a thermal image of an area of interest on the runway,

a visible light camera comprising a second field of view and adapted to capture a visible light image of the area of interest on the runway, wherein the first field of view overlaps the second field of view,

a processor in communication with the thermal camera and the visible light camera,

a memory in communication with the processor for storing instructions executable by the processor, wherein the processor is configured to,

detect a thermal object image in the thermal image,

detect a visible light object image in the visible light image,

determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively

identify and categorizing the visible light object image into an object category of the foreign object,

determine a relationship between the object category of the foreign object in the visible light image and the temperature of the foreign object in the thermal object image of the foreign object,

wherein when a thermal object image of the foreign object is detected, the foreign object is identified by mapping the object category to the temperature of the foreign object in the thermal object image based on the relationship.

15. The detection system according to claim 14, wherein to determine the foreign object, the processor is configured to generate at least one attribute of the foreign object in each of the thermal object image and visible light object image, compare the at least one attribute of the foreign object in the thermal object image and the visible light object image, wherein the foreign object is detected when the at least one attribute of the foreign object in thermal object image and the visible light object image are the same.

16. The detection system according to claim 15, wherein the at least one attribute of the foreign object comprises the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image.

17. The detection system according to claim 16, wherein the at least one attribute of the foreign object in thermal object image and the visible light object image are the same when the distance between the position of the thermal object image in the thermal image and the position of the visible light object image in the visible light image is within a position parameter.

18. The detection system according to any one of claims 15 to 17, wherein the at least one attribute of the foreign object comprises the size of the thermal object image and visible light object image.

19. The detection system according to claim 18, wherein the at least one attribute of the foreign object in the thermal object image and visible light object image are the same when the

difference in the size of the thermal object image in the thermal image and the size of the visible light object image in the visible light image is within a size parameter.

20. The detection system according to any one of claims 14 to 19, wherein the processor is further configured to zoom in the thermal camera and visible light camera to obtain an enlarged thermal object image and an enlarged visible light object image when the foreign object is detected.

21. The detection system according to any one of claims 14 to 20, wherein the processor is configured to identify an object category of the foreign object in the thermal image, wherein the processor is configured to,

segment the thermal image into a plurality of thermal image regions,

assign a feature vector to each of the plurality of thermal image regions,

compare the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category,

identify the reference feature vector closest to the feature vector and its object category.

22. The detection system according to claim 21, wherein to segment the thermal image, the processor is configured to label each pixel in the thermal image and group the labelled pixels with the same characteristic into a plurality of groups to form the plurality of thermal image regions.

23. The detection system according to any one of claims 14 to 22, wherein to identify an object category of the foreign object in the visible light image, the processor is configured to,

segment the visible light image into a plurality of visible light image regions,

assign a feature vector to each of the plurality of visible light image regions,

compare the feature vector to a plurality of reference feature vectors, wherein each of the plurality of reference feature vectors represents an object category,

identify the reference feature vector closest to the feature vector and its object category.

24. The detection system according to claim 23, wherein to segment the visible light image, the processor is configured to label each pixel in the visible light image and group the labelled pixels with the same characteristic into a plurality of groups to form the plurality of visible light image regions.

25. The detection system according to any one of claims 23 to 24, wherein the processor is further configured to train the thermal camera to detect the foreign object based on the visible light images from the visible light camera.

26. The detection system according to any one of claims 14 to 22, wherein the process is further configured to generate a thermal profile model of the foreign object and optimizing the detection configuration parameters of the thermal camera based on the thermal profile model.

27. A system for detecting a foreign object on a runway divided into a plurality of sectors, the detection system comprising,

a plurality of sets of cameras spaced apart from each other, each of the plurality of sets of cameras comprises:

a thermal camera comprising a first field of view and adapted to capture a thermal image of an area of interest on the runway,

a visible light camera comprising a second field of view and adapted to capture a visible light image of the area of interest on the runway, wherein the first field of view overlaps the second field of view,

a processor in communication with the plurality of sets of cameras,

a memory in communication with the processor for storing instructions executable by the processor, wherein the processor is configured to:

detect a thermal object image in the thermal image,

detect a visible light object image in the visible light image, and

determine that the foreign object is detected when the thermal object image and the visible light object image are detected in the thermal image and the visible light object image respectively,

identify and categorizing the visible light object image into an object category of the foreign object,

determine a relationship between the object category of the foreign object in the visible light image and the temperature of the foreign object in the thermal object image of the foreign object,

wherein when a thermal object image of the foreign object is detected, the foreign object is identified by mapping the object category to the temperature of the foreign object in the thermal object image based on the relationship,

wherein each of the plurality of sets of cameras is configured to scan one of the plurality of sectors of the runway.