CLAIMS

1. A method of processing electroluminescence (EL) images of a PV array, comprising

extracting a plurality of frames of a PV array subsection of the PV array from the EL images, the PV array subsection including one or more PV modules of the PV array;

determining a reference frame having a highest image quality of the PV array subsection from among the extracted frames;

performing image alignment of the extracted frames to the reference frame to generate image aligned frames by

arranging the extracted frames in a stacked arrangement, wherein respective corner points of the PV modules are stacked; and

aligning the respective corner points of each PV module in the extracted frames to the corresponding corner points of the PV module in the reference frame; and

processing the image aligned frames to produce an enhanced image of the PV array subsection having a higher resolution than the reference frame.

2. A method according to claim 1, wherein extracting the frames from the images comprises

determining the respective corner points of each PV module in the images; and

constructing respective frames for each PV module based on the identified corner points of each PV module.

~~3. A method according to claim 2, wherein determining respective corner points of each PV module in the images comprises~~

~~clustering the respective corner points of a particular PV module that is repeated in different images; and~~

~~computing respective averaged positions for each cluster of respective corner points.~~

43. A method according to ~~any preceding~~ claim 1 or 2, wherein determining a reference frame having a highest image quality comprises evaluating the image quality of each frame based on at least one of sharpness, signal-to-noise ratio, and completeness of the frames.

54. A method according to any ~~preceding~~ one of claims 1 to 3, wherein processing the image aligned frames comprises grouping the image aligned frames according to the PV module in each frame; and performing image averaging on each group of image aligned frames to obtain respective enhanced frames for each PV module.

~~6. A method according to claim 5, wherein the image averaging is based on weighted image stack averaging, and/or a deep convolutional neural network structure.~~

75. A method according to claim ~~5 or 6~~4, further comprising associating each enhanced frame with a horizontal index and a vertical index according to each PV module's position in the PV array subsection; and arranging the enhanced frames according to its horizontal and vertical index to produce the enhanced image of the PV array subsection.

~~8. A method according to any one of claims 5 – 7, further comprising scaling respective image intensities of each enhanced frame.~~

96. A method according to any ~~preceding~~ one of claims 1 to 5, further comprising mapping the enhanced image of the PV array subsection onto a base-map of the PV array subsection, the base-map including geo-location of each PV module.

~~10~~7. A method according to claim ~~9~~6, wherein mapping the enhanced image onto the base-map comprises orientating the enhanced image to align the PV array subsection in the enhanced image to the PV array subsection in the base-map.

~~11. A method according to claim 10, wherein each EL image of the PV array subsection includes an image identifier, and orientating the enhanced image comprises~~

~~associating the image identifier of a particular EL image with each enhanced frame having its PV module featured in the particular EL image; and~~

~~determining an orientation of the enhanced image based on the image identifiers associated with each enhanced frame.~~

~~12. A method according to any one of claims 9 – 11, wherein the geo-location includes GPS coordinates.~~

~~13. A method according to any preceding claim, wherein the plurality of frames are consecutive frames of the PV array subsection.~~

~~14~~8. An image processing device for processing EL images of a PV array, comprising

an image processor configured to

extract a plurality of frames of a PV array subsection of the PV array from the EL images, the PV array subsection including one or more PV modules of the PV array;

determine a reference frame having a highest image quality of the PV array subsection from among the extracted frames;

perform image alignment of the extracted frames to the reference frame to generate image aligned frames by

arranging the extracted frames in a stacked arrangement, wherein respective corner points of the PV modules are stacked; and

aligning the respective corner points of each PV module in the extracted frames to the corresponding corner points of the PV module in the reference frame; and

process the image aligned frames to produce an enhanced image of the PV array subsection having a higher resolution than the reference frame.

15. An image processing device according to claim 14, wherein the image processor is further configured to extract the frames from the images by

determining respective corner points of each PV module in the images; and

constructing respective frames for each PV module based on the identified corner points of each PV module.

16. An image processing device according to claim 15, wherein the image processor is further configured to determine respective corner points of each PV module in the images by

clustering the respective corner points of a particular PV module that is repeated in different images; and

computing respective averaged positions for each cluster of respective corner points.

17. An image processing device according to any one of claims 14 to 16, wherein the image processor is further configured to determine a reference frame having a highest image quality by evaluating the image quality of each frame based on at least one of sharpness, signal-to-noise ratio, and completeness of the frames.

18. An image processing device according to any one of claims 14 to 17, wherein the image processor is further configured to process the image aligned frames by grouping the image aligned frames according to the PV module in each frame; and perform image averaging on each group of image aligned frames to obtain respective enhanced frames for each PV module.

19. An image processing device according to claim 18, wherein the image processor is further configured to perform image averaging based on weighted image stack averaging, and/or a deep convolutional neural network structure.

20. An image processing device according to claim 18 or 19, wherein the image processor is further configured to associate each enhanced frame with a horizontal index and a vertical index according to each PV module's position in the PV array

~~subsection; and arrange the enhanced frames according to its horizontal and vertical index to produce the enhanced image of the PV array subsection.~~

~~21. An image processing device according to any one of claims 18 to 20, wherein the image processor is further configured to scale respective image intensities of each enhanced frame.~~

~~22. An image processing device according to any one of claims 14 to 21, wherein the image processor is further configured to map the enhanced image of the PV array subsection onto a base-map of the PV array subsection, the base-map including geo-location of each PV module.~~

~~23. An image processing device according to claim 22, wherein the image processor is further configured to map the enhanced image onto the base-map by orientating the enhanced image to align the PV array subsection in the enhanced image to the PV array subsection in the base-map.~~

~~24. An image processing device according to claim 23, wherein each EL image of the PV array subsection includes an image identifier, and the image processor is further configured to orientate the enhanced image by~~

~~associating the image identifier of a particular EL image with each enhanced frame having its PV module featured in the particular EL image; and~~

~~determining an orientation of the enhanced image based on the image identifiers associated with each enhanced frame.~~

~~25. An image processing device according to any one of claims 22 to 24, wherein the geo-location includes GPS coordinates.~~

~~26. An image processing device according to any one of claims 14 to 25, wherein the plurality of frames are consecutive frames of the PV array subsection.~~

~~27~~9. A method of controlling movement of an aerial vehicle having a camera for capturing EL images of a PV array, the method comprising

controlling the aerial vehicle to fly along a flight path to capture EL images of corresponding PV array subsections of the PV array;

deriving respective image quality parameters from at least some of the captured EL images, wherein the image quality parameters include a SNR scanning factor and a motion blur scanning factor; and

dynamically adjusting a flight speed of the aerial vehicle along the flight path, based on the respective image quality parameters for capturing the EL images of the PV array subsections by

deriving a target flight speed based on a minimum of the SNR scanning factor and the motion blur scanning factor; and

dynamically adjusting the current flight speed of the aerial vehicle to match the target flight speed.

~~28~~10. A method of claim ~~27~~9, wherein the SNR scanning factor is dependent on a target SNR, a measured SNR, and an estimated number of EL images captured that include a particular PV module of the PV array subsection.

~~29. A method of claim 27 or 28, wherein the motion blur scanning factor is a ratio of a measured object deflection to a predefined maximum object deflection.~~

~~30~~11. A method of claim ~~27~~9, wherein deriving the target flight speed comprises

applying the minimum of the SNR scanning factor and the motion blur scanning factor to a current flight speed of the aerial vehicle to derive a target scanning speed; and

selecting the target scanning speed as the target flight speed if the target scanning speed is below a maximum flight speed of the aerial vehicle.

~~31. A method of claim 30, further comprising selecting the maximum flight speed as the target flight speed if the target scanning speed exceeds the maximum flight speed of the aerial vehicle.~~

~~32. A method of any one of claims 27 to 31, further comprising adjusting the target flight speed based on a user input factor.~~

~~33~~12. A method according to any one of claims ~~27~~ 9 to ~~32~~11, further comprising detecting an EL signal emitted by one or more PV modules from the PV array, prior to controlling the aerial vehicle to fly along the flight path to capture EL images of corresponding PV array subsections of the PV array.

~~34~~13. A method according to claim ~~33~~12, further comprising manoeuvring the aerial vehicle to an initial position wherein the aerial vehicle's yaw axis and the camera's optical axis are perpendicular to the ground before detecting the EL signal.

~~35. A method according to claim 33 or 34, further comprising navigating the aerial vehicle to the EL signal's location.~~

~~36. A method according to any one of claims 33 – 35, wherein detecting the EL signal emitted by the one or more PV modules of the PV array comprises rotating the aerial vehicle about the vehicle's yaw axis while simultaneously increasing the camera's optical axis angle until the EL signal is detected.~~

~~37. A method according to claim 36, wherein the camera's optical axis angle is increased from 0° to 70°.~~

~~38. A method according to claim 36 or 37, wherein the camera's optical axis angle is increased at a decreasing pitch speed.~~

~~39. A method according to any one of claims 36 – 38, wherein the aerial vehicle rotates at a decreasing yaw speed.~~

~~40. A method according to any one of claims 36 – 39, further comprising maneuvering the aerial vehicle to a predefined elevation before rotating the aerial vehicle.~~

~~41~~14. A method according to any one of claims ~~27 – 40~~9 to 13, further comprising aligning the camera's field-of-view (FOV) to the corresponding PV array subsections

by determining respective key points of a reference PV module in the corresponding PV array subsections;

deriving target aligned points from the respective key points for the camera's FOV to be aligned to the corresponding PV array subsections;

performing a perspective transformation to align the respective key points to the target aligned points; and

maneuvering the aerial vehicle relative to the corresponding PV array subsections based on the perspective transformation.

~~42~~15. A method according to claim ~~41~~14, wherein aligning the camera's FOV to the corresponding PV array subsections further comprises manoeuvring the aerial vehicle to an appropriate elevation, wherein the corresponding PV array subsections are at a predefined size ratio within the camera's FOV at the appropriate elevation.

~~43. A method according to claim 42, wherein the corresponding PV array subsections occupy 80% to 90% of the camera's FOV at the predefined size ratio.~~

~~44. A method according to any one of claims 27 – 43, further comprising dynamically adjusting the camera's focus according to a measured image sharpness.~~

~~45. A method according to any one claims 27 – 44, wherein the aerial vehicle further includes a light source aligned with the camera's optical axis, and the method further comprises powering the light source except while capturing the EL images of the PV array.~~

~~46~~16. An aerial vehicle, comprising

a camera for capturing EL images of a PV array;

a propulsion device for actuating movement of the aerial vehicle; and

a controller communicatively coupled to the camera and the propulsion device and configured to

controlling the aerial vehicle to fly along a flight path to capture EL images of corresponding PV array subsections of the PV array;

deriving respective image quality parameters from at least some of the captured EL images, wherein the image quality parameters include a SNR scanning factor and a motion blur scanning factor; and

dynamically adjusting a flight speed of the aerial vehicle along the flight path, based on the respective image quality parameters for capturing the EL images of the PV array subsections by

deriving a target flight speed based on the minimum of a SNR scanning factor and the motion blur scanning factor; and

dynamically adjusting the current flight speed of the aerial vehicle to match the target flight speed.

~~47. The aerial vehicle of claim 46, wherein the SNR scanning factor is dependent on a target SNR, a measured SNR, and an estimated number of EL images captured that include a particular PV module of the PV array subsection.~~

~~48. The aerial vehicle of claim 46 or 47, wherein the motion blur scanning factor is a ratio of a measured object deflection to a predefined maximum object deflection.~~

~~49. The aerial vehicle of claim 46, wherein the controller is further configured to deriving the target flight speed by~~

~~applying the minimum of the SNR scanning factor and the motion blur scanning factor to a current flight speed of the aerial vehicle to derive a target scanning speed; and~~

~~selecting the target scanning speed as the target flight speed if the target scanning speed is below a maximum flight speed of the aerial vehicle.~~

~~50. The aerial vehicle of claim 49, wherein the controller is further configured to select the maximum flight speed as the target flight speed if the target scanning speed exceeds the maximum flight speed of the aerial vehicle.~~

~~51. The aerial vehicle of any one of claims 46 to 50, wherein the controller is further configured to adjust the target flight speed based on a user input factor.~~

~~52~~17. The aerial vehicle of ~~any one of claims 46 to 51~~claim 16, wherein the controller is further configured to

detect an EL signal emitted by one or more PV modules from the PV array, the PV array having an array axis, and the one or more PV modules being aligned to the array axis and includes a planar surface;

determine the array axis of the PV array; and

control the camera to capture the EL images of the PV array along the array axis while dynamically adjusting the propulsion device to align the camera's optical axis to be perpendicular to the one or more PV module's planar surface.

~~53. An aerial vehicle according to claim 52, wherein the controller is further configured to set the aerial vehicle to an initial position before locating the EL signal by~~

~~dynamically adjusting the propulsion device to set the aerial vehicle's yaw axis to be perpendicular to the ground; and~~

~~dynamically adjusting the camera's optical axis to be perpendicular to the ground.~~

~~54. An aerial vehicle according to claim 52 or 53, wherein the controller is further configured to dynamically adjust the propulsion device to navigate the aerial vehicle to the EL signal's location.~~

~~55~~18. An aerial vehicle according to ~~any one of claims 52 to 54~~claim 17, wherein the controller is further configured to locate the EL signal emitted by the one or more PV modules of the PV array by dynamically adjust the propulsion device to rotate the aerial vehicle about the vehicle's yaw axis while simultaneously increasing the camera's optical axis angle until the EL signal is located.

~~56. An aerial vehicle according to claim 55, wherein the camera's optical axis angle is increased from 0° to 70°.~~

~~57. An aerial vehicle according to claim 55 or 56, wherein the camera's optical axis angle is increased at a decreasing pitch speed.~~

~~58. An aerial vehicle according to any one of claims 55 to 57, wherein the aerial vehicle rotates at a decreasing yaw speed.~~

~~59. An aerial vehicle according to any one of claims 55 to 58, wherein the controller is further configured to dynamically adjust the propulsion device to maneuver the aerial vehicle to a predefined elevation before rotating the aerial vehicle.~~

~~60. An aerial vehicle according to any one of claims 52 to 59, wherein the controller is further configured to align the camera's field-of-view (FOV) to the corresponding PV array subsections by~~

~~determining respective key points of a reference PV module in the corresponding PV array subsections; deriving target aligned points from the respective key points for the camera's FOV to be align to the corresponding PV array subsections;~~

~~performing a perspective transformation to align the respective key points to the target aligned points; and~~

~~dynamically adjusting the propulsion device to maneuver the aerial vehicle relative to the corresponding PV array subsection based on the perspective transformation.~~

~~61. An aerial vehicle according to claim 60, wherein the controller is further configured to align the camera's FOV to the corresponding PV array subsections by dynamically adjusting the propulsion device to maneuver the aerial vehicle to an appropriate elevation, wherein the corresponding PV array subsections are at a predefined size ratio within the camera's FOV at the appropriate elevation.~~

~~62. An aerial vehicle according to claim 61, wherein the corresponding PV array subsections occupy 80% to 90% of the camera's FOV at the predefined size ratio.~~

~~63. An aerial vehicle according to any one of claims 52 to 62, wherein the controller is further configured to dynamically adjust the camera's focus according to a measured image sharpness.~~

~~64. An aerial vehicle according to any one of claims 52 to 63, further comprising a light source aligned with the camera's optical axis, and the controller is further configured to power the light source except while capturing the EL images of the PV array.~~

~~65~~19. A method of obtaining an enhanced image of a PV array subsection of a PV array from EL images of the PV array subsection captured by an aerial vehicle having a camera, the method comprising

controlling the aerial vehicle to fly along a flight path to capture EL images of corresponding PV array subsections of the PV array;

deriving respective image quality parameters from at least some of the captured EL images;

dynamically adjusting a flight speed of the aerial vehicle along the flight path, based on the respective image quality parameters for capturing the EL images of the PV array subsections;

extracting a plurality of frames of the PV array subsection from the EL images; determining a reference frame having a highest image quality of the PV array subsection from among the extracted frames;

performing image alignment of the extracted frames to the reference frame to generate image aligned frames by

arranging the extracted frames in a stacked arrangement, wherein respective corner points of the PV modules are stacked; and

aligning the respective corner points of each PV module in the extracted frames to the corresponding corner points of the PV module in the reference frame; and

processing the image aligned frames to produce an enhanced image of the PV array subsection having a higher resolution than the reference frame.

~~66~~20. A system for capturing and processing EL images of a PV array subsection of a PV array, comprising

an aerial vehicle including

a camera for capturing EL images of a PV array;

a propulsion device for actuating movement of the aerial vehicle; and

a controller communicatively coupled to the camera and the propulsion device and configured to

controlling the aerial vehicle to fly along a flight path to capture EL images of corresponding PV array subsections of the PV array;

deriving respective image quality parameters from at least some of the captured EL images; and

dynamically adjusting a flight speed of the aerial vehicle along the flight path, based on the respective image quality parameters for capturing the EL images of the PV array subsections; and

an image processing device including

an image processor configured to

extract a plurality of frames of a PV array subsection of the PV array from the EL images, the PV array subsection including one or more PV modules of the PV array;

determine a reference frame having a highest image quality of the PV array subsection from among the extracted frames;

perform image alignment of the extracted frames to the reference frame to generate image aligned frames by

arranging the extracted frames in a stacked arrangement, wherein respective corner points of the PV modules are stacked; and

aligning the respective corner points of each PV module in the extracted frames to the corresponding corner points of the PV module in the reference frame; and

process the image aligned frames to produce an enhanced image of the PV array subsection having a higher resolution than the reference frame.