

SYSTEMS AND METHODS OF IMAGE ACQUISITION

TECHNICAL FIELD

The presently disclosed subject matter relates to image acquisition from a scanning vehicle such as an airborne, a satellite, or from an imager which can be located
5 on ground.

BACKGROUND

In the push-broom solution, a linear array detector is arranged perpendicular to the flight direction of a satellite. The linear array detector advances with the satellite's
10 motion, producing successive lines of image data.

In this solution, a smearing effect can alter quality of the images. In addition, this solution generally requires TDI (Time Delay and Integration) detectors which are expensive.

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GENERAL DESCRIPTION

In accordance with certain aspects of the presently disclosed subject matter, there is provided an imaging system comprising at least one camera, comprising at least one sensor comprising one or more pixel bands each configured to acquire an image of
20 a fraction of a scene, wherein the sensor is movable, by at least one actuator, relative to the camera along at least one direction, a processing unit and associated memory configured to, while a line of sight of the camera is maintained fixedly oriented towards a target of a scene: (O₁) control the camera to acquire an image by each of the pixel bands of the sensor located at a current position relative to the camera, (O₂) send a
25 command to the actuator to move the sensor relative to the camera along the at least one direction, from the current position to a new position, and (O₃) control the camera to acquire an image by each of the pixel bands of the sensor, wherein motion of the sensor at O₂ from the current position to the new position is performed during a period of time PT₁, and the sensor is retained stationary at the new position during a period of
30 time PT₂, wherein acquisition of the image by each of the pixel bands of the sensor at O₃ is performed during period of time PT₃, wherein at least a majority of the period of time PT₃ is within the period of time PT₂.

In addition to the above features, the imaging system according to this aspect of the presently disclosed subject matter can optionally comprise one or more of features (i) to (x) below, in any technically possible combination or permutation:

- i. the system is configured to be mounted on an airborne or a satellite,
5 wherein the line of sight of the camera is maintained fixedly oriented towards the target of the scene during motion of the airborne or satellite;
- ii. the system is configured to be part of a ground imager;
- iii. all of the period of time PT_3 is within the period of time PT_2 ;
- iv. the processing unit is configured to repeat (O_2) and (O_3) a plurality of
10 times, until acquisition of at least part of the scene, or of the whole scene, by each of the pixel bands, is obtained;
- v. the processing unit and associated memory are configured to, for a plurality of different scenes SC_1 to SC_N , with $N > 1$, repetitively perform, from i equal to 1 up to i equal to N : $(O_{0,i})$ while a line of sight of the camera is maintained fixedly oriented towards a target of a scene SC_i : $(O_{1,i})$ control the camera to acquire, by each of one or more pixel bands of the sensor located at a current position relative to the camera, an image of a fraction of scene SC_i , $(O_{2,i})$ send a command to the actuator to move the sensor relative to the camera along the at least one direction, from the current
15 position to a new position, and $(O_{3,i})$ control the camera to acquire, by each of one or more pixel bands of the sensor located at the new position relative to the camera, an image of a fraction of at least scene SC_i , wherein motion of the sensor at $O_{2,i}$ from the current position to the new position is performed during a first period of time $PT_{1,i}$, and the sensor is retained stationary at the new position during a second period of time $PT_{2,i}$, wherein acquisition of the image at $O_{3,i}$ is performed during a third period of time $PT_{3,i}$, wherein at least a majority of the third period of time $PT_{3,i}$ is within the second period of time $PT_{2,i}$, $(O_{3,i})$ revert to operation $O_{2,i}$, wherein, after a period of time, i is incremented by one and it is reverted to operation $O_{0,i}$;
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vi. an orientation of the line of sight toward a target of scene SC_i is changeable to an orientation toward a target of scene SC_{i+1} by performing a manoeuvre of a vehicle on which the imaging system is mounted;
- vii. each of the pixel bands is configured to acquire images in a different spectral range; and the camera is controlled so that each pixel band of the

camera gradually acquires an image of each of a plurality of the scenes SC_i as a whole in its spectral range, thereby providing an image of each of the plurality of the scenes SC_i in its spectral range;

- 5 viii. the sensor is a two dimensional sensor comprising a plurality of pixel bands;
- ix. while a line of sight of the camera is maintained fixedly oriented towards a target of a scene, a direction of motion of the sensor from the current position to the new position is not opposite to a direction of motion of a vehicle on which the imaging system is mounted; and
- 10 x. the sensor comprises a plurality of pixel bands having a similar width, wherein the processing unit is configured to induce motion of the sensor relative to the camera along a distance substantially equal to the width, or smaller than the width.

According to another aspect of the presently disclosed subject matter there is
15 provided an imaging method comprising: providing at least one camera, wherein the camera comprises at least one sensor comprising one or more pixel bands each configured to acquire an image of a fraction of a scene, while a line of sight of the camera is maintained fixedly oriented towards a target of a scene: (O₁) controlling the camera to acquire an image by each of the pixel bands of the sensor located at a current position
20 relative to the camera, (O₂) sending a command to an actuator of the sensor, for inducing a motion of the sensor relative to the camera along at least one direction, from a current position to a new position, (O₃) controlling the camera to acquire an image by each of the pixel bands of the sensor, wherein motion of the sensor from the current position to the new position is performed during a first period of time PT₁, and the sensor is retained
25 stationary at the new position during a second period of time PT₂, wherein acquisition of the image by each of the pixel bands of the sensor is performed during a third period of time PT₃, wherein at least a majority of the third period of time PT₃ is within the second period of time PT₂.

In addition to the above features, the method according to this aspect of the
30 presently disclosed subject matter can optionally comprise one or more of features (xi) to (xx) below, in any technically possible combination or permutation:

- xi. the camera is mounted on an airborne or a satellite, wherein the line of sight of the camera is maintained fixedly oriented towards the target of the scene during motion of the airborne or satellite;

- xii. the camera is part of a scanning imager including a basement which orientation is controllable to modify an orientation of the line of sight of the camera;
- xiii. all of the third period of time PT_3 is within the second period of time PT_2 ;
- 5 xiv. the method comprises repeating (O_2) and (O_3) a plurality of times, until acquisition of at least part of the scene, or of the whole scene, by each of the pixel bands, is obtained;
- xv. the method comprises, for a plurality of different scenes SC_1 to SC_N , with $N > 1$, repetitively performing, from i equal to 1 up to i equal to N : $(O_{0,i})$
10 while a line of sight of the camera is maintained fixedly oriented towards a scene SC_i : $(O_{1,i})$ controlling the camera to acquire, by each of one or more pixel bands of the sensor located at a current position relative to the camera, an image of a fraction of scene SC_i , $(O_{2,i})$ sending a command to the actuator to move the sensor relative to the camera along the at least one
15 direction, from the current position to a new position, and $(O_{3,i})$ controlling the camera to acquire, by each of one or more pixel bands of the sensor located at the new position relative to the camera, an image of a fraction of at least scene SC_i , wherein motion of the sensor at $O_{2,i}$ from the current position to the new position is performed during a first period of time $PT_{1,i}$,
20 and the sensor is retained stationary at the new position during a second period of time $PT_{2,i}$, wherein acquisition of the image at $O_{3,i}$ is performed during a third period of time $PT_{3,i}$, wherein at least a majority of the third period of time $PT_{3,i}$ is within the second period of time $PT_{2,i}$, $(O_{3,i})$ reverting to operation $O_{2,i}$, wherein, after a period of time, i is incremented
25 by one and it is reverted to operation $O_{0,i}$;
- xvi. the method comprises changing orientation of the line of sight toward a target of scene SC_i to an orientation toward a target of scene SC_{i+1} by performing a manoeuvre of a vehicle on which the camera is mounted;
- xvii. each of the pixel bands is configured to acquire images in a different
30 spectral range and the camera is controlled so that each pixel band of the camera gradually acquires an image of each of a plurality of the scenes SC_i as a whole in its spectral range, thereby providing an image of each of the plurality of the scenes SC_i in its spectral range;

- xviii. the sensor is a two dimensional sensor comprising a plurality of pixel bands;
- xix. while a line of sight of the camera is maintained fixedly oriented towards a target of a scene, a direction of motion of the sensor from the current position to the new position is not opposite to a direction of motion of a vehicle on which the camera is mounted;
- xx. the sensor comprises a plurality of pixel bands having a similar width, wherein the method comprises moving the sensor relative to the camera along a distance substantially equal to the width, or smaller than the width.

According to another aspect of the presently disclosed subject matter there is provided a non-transitory computer readable medium comprising instructions that, when executed by a processing unit and associated memory, cause the processing unit and associated memory to perform operations comprising: while a line of sight of a camera is maintained fixedly oriented towards a target of a scene, wherein the camera comprises at least one sensor comprising one or more pixel bands, (O₁) controlling the camera to acquire an image by each of the pixel bands of the sensor located at a current position relative to the camera, (O₂) sending a command to an actuator of the sensor, for inducing a motion of the sensor relative to the camera along at least one direction, from a current position to a new position, (O₃) controlling the camera to acquire an image by each of the pixel bands of the sensor, wherein motion of the sensor from the current position to the new position is performed during a first period of time PT₁, and the sensor is retained stationary at the new position during a second period of time PT₂, wherein acquisition of the image by each of the pixel bands of the sensor is performed during a third period of time PT₃, wherein at least a majority of the third period of time PT₃ is within the second period of time PT₂.

In addition to the above features, the non-transitory computer readable medium comprises instructions that, when executed by a processing unit and associated memory, cause the processing unit and associated memory to perform operations according to any one or more of features (x) to (xx) above.

According to some embodiments, the proposed solution provides a simple and cost effective solution to acquire images.

According to some embodiments, the proposed solution provides acquisition of a panchromatic image of a scene with a two dimensional sensor which can be both of large dimensions and cost effective.

According to some embodiments, the proposed solution provides acquisition of a scene in different spectral bands, in a simple and efficient way, which does not require cumbersome post-processing.

5 According to some embodiments, the proposed solution provides acquisition of a scene in a way which reduces smearing effect which can be caused by motion of a scanning vehicle such as an airborne or a satellite.

According to some embodiments, the proposed solution provides acquisition of an image of a scene with a better quality than other prior art methods.

10 According to some embodiments, the proposed solution provides acquisition of an image of a scene without requiring transmission of high volume of data between an airborne (or a satellite) and a ground station.

According to some embodiments, the proposed solution provides acquisition of a scene with an integration time which is higher relative to some prior art solutions, thereby avoiding use of complicated and costly sensors such as TDI (time delay
15 integration) sensors.

In particular, according to some embodiments, the proposed solution allows acquisition of the image while the airborne or satellite is staring at the scene to be acquired, thereby improving signal to noise ratio.

20 BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it can be carried out in practice, embodiments will be described, by way of non-limiting examples, with reference to the accompanying drawings, in which:

- 25 - **Fig. 1** illustrates an embodiment of a system which can be used to perform one or more of the methods described hereinafter;
- **Fig. 1A** illustrates another embodiment of a system which can be used to perform one or more of the methods described hereinafter;
- **Fig. 1B** illustrates the system of **Fig. 1** mounted e.g. on an airborne or satellite in order to acquire images of a scene;
- 30 - **Fig. 1C** illustrates a method of maintaining line of sight of a camera of e.g. an airborne or satellite towards a fixed target of a scene, while the airborne or satellite is moving;

- **Fig. 1D** illustrates the system of **Fig. 1A** mounted e.g. on an airborne or satellite in order to acquire images of a scene;
- **Fig. 2** illustrates a method allowing acquisition of at least part of a scene, using the system of **Fig. 1** or **Fig. 1A**;
- 5 - **Fig. 3A** illustrates velocity of a motor of an actuator configured to move a sensor in the system of **Fig. 1** or **Fig. 1A**, with respect to time;
- **Fig. 3B** illustrates a possible sequence of image acquisition by the camera in the system of **Fig. 1** or **Fig. 1A**, with respect to time;
- **Fig. 3C** illustrates another possible sequence of image acquisition by the camera
10 in the system of **Fig. 1** or **Fig. 1A**, with respect to time;
- **Fig. 3D** illustrates an iterative method of acquiring images of a plurality of scenes;
- **Figs. 3E to 3M** illustrate examples of acquiring images of a plurality of scenes, according to the method of **Fig. 3D**; and
- 15 - **Figs. 4 to 4B** illustrate an example of acquiring images of a scene, using the system of **Fig. 1A**.

DETAILED DESCRIPTION

20 In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the presently disclosed subject matter may be practiced without these specific details. In other instances, well-known methods have not been described in detail so as not to obscure the presently disclosed subject matter.

25 Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "sending", "controlling", "acquiring", or the like, refer to the action(s) and/or process(es) of a processing unit that manipulate and/or transform data into other data, said data represented as physical, such as electronic, quantities and/or said data
30 representing the physical objects.

The term "processing unit" as disclosed herein should be broadly construed to include any kind of electronic device with data processing circuitry, which includes for example a computer processing device operatively connected to a computer memory (e.g. digital signal processor (DSP), a microcontroller, a field programmable gate array

(FPGA), and an application specific integrated circuit (ASIC), etc.) capable of executing various data processing operations.

The processing unit can encompass a single processor or multiple processors, which may be located in the same geographical zone or may, at least partially, be
5 located in different zones and may be able to communicate together.

The term "non-transitory memory" as used herein should be expansively construed to cover any volatile or non-volatile computer memory suitable to the presently disclosed subject matter.

Fig. 1 illustrates an embodiment of a system **100** which can be used for
10 acquiring images of a scene.

System **100** can be mounted or affixed to a scanning vehicle such as an airborne (e.g. plane, drone, etc.), or a satellite.

In some embodiments, system **100** can be mounted on a terrestrial scanning vehicle, such as a car.

15 In some embodiments, system **100** can be part of an imager, which can be located on ground.

In some embodiments, the imager (device for acquiring images using the camera of system **100**) can be located on a basement (such as a tripod). Orientation of the basement can be modified to change the orientation of the line of sight of a camera
20 of the imager, thereby allowing acquisition of images of different scenes.

In other embodiments, the imager can be handled by a user who can manually change line of sight of the camera by changing orientation of the imager.

As shown, system **100** comprises at least one camera **120**. Camera **120** comprises at least one sensor **130** (imaging sensor, also called photon detector)
25 comprising a plurality of pixels. Photons reflected or transmitted by a scene to be observed are collected by an optics **170** of camera **120** and are sensed by sensor **130**. Camera **120** can comprise various other elements (electric elements, optical elements) which are not described since they are part of a regular camera.

According to some embodiments, and as shown in **Fig. 1**, sensor **130** comprises
30 a plurality of pixels **140**.

According to some embodiments, and as shown in **Fig. 1**, sensor **130** is a two dimensional sensor which can comprise a plurality of pixel bands (or pixel stripes - see reference **150₁**, **150₂**, ..., **150₄**). In **Fig. 1**, four pixel bands are depicted. This number is not limitative and other numbers can be used.

According to some embodiments, the different pixel bands are part of a common two-dimensional sensor. In particular, the different pixel bands can belong to the same physical pixel matrix.

5 According to other embodiments, each pixel band is physically distinct from the other pixel bands, and is not necessarily mechanically and/or electronically connected to the other pixel bands. However, the different pixel bands constitute together an assembly which can be viewed a two dimensional sensor.

Each pixel band comprises a plurality of pixel lines. According to some embodiments, and as explained hereinafter, each pixel band can be configured to detect
10 light in a different spectral range. In order to obtain this multi-spectral detection, each pixel band can be associated with a different optical filter. In particular, each optical filter can be configured to transmit light in a different spectral range.

Each optical filter can be affixed e.g. to the surface of a corresponding pixel band, or can be located in the vicinity of a corresponding pixel band. According to some
15 embodiments, the optical filters can be affixed directly to the die (which includes the pixels), or on the sensor windows (several millimeters above the die).

As shown in **Fig. 1**, sensor **130** can be associated with at least one actuator **160**. Actuator **160** can be part of camera **120** (e.g. it can be located within camera **120**). Actuator **160** is configured to move sensor **130**. According to some embodiments,
20 actuator **160** is configured to move sensor **130** according to at least one direction (translation).

In particular, actuator **160** can move sensor **130** relative to the camera **120** itself, and therefore, relative to the airborne or satellite on which the camera **120** is affixed. In other words, in a referential associated with the camera (or in some embodiments in
25 a referential associated with the airborne or the satellite), the sensor **130** is movable along at least one direction.

In some embodiments, actuator **160** moves the whole sensor **130**, and therefore, each of the pixel band of sensor **130** is moved accordingly.

According to some embodiments, an actuator can move sensor **130** along more
30 than one direction. For this purpose, at least two different actuators can be used (one per direction, see reference **160** and **165**). According to some embodiments, a single actuator with at least two degrees of freedom can be used, thereby allowing motion of the sensor according to two directions.

Examples of actuator can include e.g. piezo-electric actuators, acoustic actuator, electric actuators, pneumatic actuators, hydraulic actuators, etc.

As shown in **Fig. 1**, system **100** can comprise a processing unit and a memory (e.g. non-transitory memory), represented by reference **110** in **Fig. 1**.

5 In some embodiments, the processing unit and memory are not part of system **100** but are operatively connected with system **100**.

The processing unit can in particular send commands to the camera **120**, in order to control acquisition of images by sensor **130**, and can also send commands (directly, and/or through the camera) to the actuator **160** for controlling motion of sensor **130**.

10 According to other embodiments (see **Fig. 1A**), sensor **130** can comprise a single pixel band **150s** comprising a plurality of pixel lines. In this case, sensor **130** generally operates in a single spectral range.

Attention is now drawn to **Fig. 1B**.

Assume system **100** is mounted on a satellite **180** (this example is not limitative, and as already explained above, system **100** can be also mounted on other platforms). Assume image of a scene **185** has to be captured by the camera **120** comprising sensor **130** and optics **170**, which collects light and directs it towards sensor **130**. As shown in **Fig. 1B**, satellite **180**, which is in orbital motion around Earth, is currently oriented towards the scene **185**.

20 According to some embodiments, a line of sight **190** of the camera **120** is maintained (substantially) fixedly oriented towards a target of the scene **185** which is covered by the camera field of view (the target is generally fixed relative to the scene) on Earth, although the satellite is in constant orbital motion around Earth. The line of sight **190** can be defined e.g. as the central line of the optical field of view (FOV) of the camera which is oriented toward the scene. As explained above, the sensor **130** is movable relative to the camera. Field of view of the sensor **130** is generally smaller than field of view of the camera **120**, and the sensor **130** is moved such as its field of view remains located within the larger field of view of the camera.

As shown in **Fig. 1C**, the line of sight **190** of the camera **120** of the satellite **180** is maintained oriented towards a (fixed) target **196** of the scene **185**, by modifying the direction and/or orientation (also called attitude) of the satellite **180** during its orbital motion around Earth.

Although the line of sight **190** is always pointing during this period of time towards the same target **196**, its inclination relative to Earth evolves over time, as a consequence of the satellite **180** motion and orbiting over time.

According to some embodiments, control moment gyroscopes (CMG) embedded on the satellite **180** can be used to modify direction and/or orientation of the satellite **180** and therefore to maintain a fixed line of sight of the camera **120**.

In some examples, this relative static position of the satellite **180** relative to the scene **185** can be maintained during a period of time of several tens of seconds (this is however not limitative).

The same principles can be used in some embodiments for an airborne (e.g. drone).

In some embodiments, the line of sight of the camera is maintained fixedly oriented towards a target of the scene by modifying orientation and/or direction of a basement on which the camera of system **100** is mounted. For example, one or more gimbals can be used to modify orientation of the basement, and as a consequence, to modify orientation of the line of sight of the camera.

According to some embodiments, this solution can be used when system **100** is located on a scanning vehicle (e.g. plane, drone, car, etc. – this could be used even for a satellite), and therefore, during motion of the scanning vehicle, line of sight of the camera is maintained fixedly oriented towards a target of the scene by using gimbals modifying orientation of the basement (instead of modifying orientation of the scanning vehicle).

In some embodiments, a double motion can be used to maintain fixed line of sight of the camera: a modification of the orientation of the scanning vehicle itself is performed during its motion (as explained above with reference to **Fig. 1C**), in combination with a modification of the orientation of the basement on which system **100** is located (using e.g. gimbals as explained above).

As already mentioned above, system **100** is not necessarily mounted on a scanning vehicle and can be part, in some embodiments, of an imager located e.g. on ground. The imager can be mounted on a basement located on ground. Orientation of the basement on which the camera of system **100** is located can be modified over time (using e.g. a tripod as basement, which can be e.g. rotated). During a first period of time, the basement is oriented so that the line of sight of the camera is oriented towards a fixed target of a first scene, during a second period of time, the basement is rotated to

orient the light of sight towards fixed target of a second scene, etc. Therefore, it is possible to obtain a fixed line of sight of the camera towards a fixed target of a different scene for each period of time.

5 If the imager is handled by a user, the user can manually change the line of sight of the camera: during a first period of time, the user orients the line of sight of the camera towards a first scene, during a second period of time, the user orients the line of sight of the camera towards a second scene, etc.

As visible in **Fig. 1B**, sensor **130** comprises a plurality of pixel bands **150₁**, ..., **150₅**. As shown, when the line of sight **190** of the camera **120** is fixed towards a target of the scene, and actuator **160** does not move sensor **130**, each pixel band acquires only
10 a fraction of the scene (each pixel band acquires a different fraction of the scene – in some embodiments, the different fractions can partially overlap). In the example of **Fig. 1B**, each pixel band **150_i** acquires only fraction **185_i** of the scene **185**, for *i* from 1 to 5.

The same applies when sensor **130** comprises a single pixel band **150₅** (as depicted in **Fig. 1A**). This is shown in **Fig. 1D**, in which pixel band **150₅** acquires only
15 a fraction **185₃** of the scene **185** to be captured by the camera **120**.

Attention is now drawn to **Fig. 2**, which describes a method allowing acquisition of at least one scene, using system **100**. As mentioned above, system **100** can be mounted on a scanning vehicle such as an airborne, a satellite, etc., or system **100** can
20 be part of an imager located e.g. on ground.

Assume that line of sight of the camera **120** is maintained (see reference **200**) fixedly oriented towards a fixed target of a scene (using at least one of the various methods described explained above).

Assume the sensor **130** is located at a current position with respect to the camera
25 **120**. In this current position of the sensor **130** relative to the camera **120**, each pixel band of the sensor **130** acquires a fraction of the scene (operation **201**).

The method can comprise sending (operation **205**) a command (e.g. by the processing unit and memory **110**) to the actuator **160** of the sensor **130**, for inducing a motion of the sensor **130** relative to the camera **120** along at least one direction. The
30 command can be sent to the actuator **160** itself, or to the camera **120** which transmits the command to the actuator **160**.

The sensor **130** moves, as a consequence of the action of the actuator, from its current position to a new position relative to the camera **120**. As explained with

reference to **Fig. 3A** (see period of time PT_2), the sensor **130** is retained stationary at its new position, in order to acquire a new image of the scene.

If the actuator **160** moves the sensor **130** according to one direction, then the motion is a translation of the sensor **130** from the current position to the new position.

5 The method can comprise controlling (operation **210**) the camera **120** to acquire an image by each of the pixel bands of the sensor **130** located at the new position.

In particular, each pixel band can now acquire a different fraction of a scene, depending on its position relative to the scene.

10 The method can be repeated a plurality of times, as indicated by arrow **220** in **Fig. 2**.

In particular, the iterative process of:

- (1) moving the sensor relative to the camera (operation **205**),
- (2) acquiring (operation **210**) an image by the sensor when it has joined its new position and is retained stationary at its new position (sensor is static relative to the camera), and
- 15 (3) reverting to (1) (operation **220**)

can be performed while a line of sight of the camera is maintained (substantially) fixedly oriented towards a target of a scene.

20 Attention is drawn to **Figs. 3A** to **3C**, which describe a temporal sequence of image acquisition in compliance with the method of **Fig. 2**.

Fig. 3A illustrates velocity of a motor of the actuator **160** with respect to time. As visible in **Fig. 3A**, the method comprises a first period of time PT_1 in which the actuator **160** is active and moves the sensor **130** from its current position to its new position (in compliance with reference **205** of **Fig. 2**).

25 The method comprises a second period of time PT_2 in which the sensor **130** is retained stationary (relative to the camera) at its new position (period of time PT_2 ends up when the actuator is again activated to further move the sensor **130** to another new position).

30 As shown in **Figs. 3B** and **3C**, acquisition of the image by each pixel band is performed during a third period of time PT_3 .

According to some embodiments, and as shown in **Fig. 3B**, the third period of time PT_3 is totally within (or equal to) the second period of time PT_2 (e.g. $PT_3 \in PT_2$, or $PT_3 = PT_2$). In other words, image acquisition is performed only when actuator **160** is

not moving sensor **130**, that it to say only when sensor **130** has reached his new position and is retained stationary at this new position during period of time PT_2 .

According to some embodiments, and as shown in **Fig. 3C**, at least a majority of the third period of time PT_3 is within the second period of time PT_2 . In other words, most
5 of the image acquisition is performed while the sensor **130** is fixed at its new position, and a minority of the image acquisition is performed while actuator **160** is moving sensor **130** (e.g. during period PT_1 located in time before period PT_2 , and/or during period PT_1 located in time after period PT_2 , that it to say when the method is repeated to make the sensor **130** join a second new position). This motion will not significantly affect the image quality
10 since the velocity of the sensor during this short period of time is generally slow (since it corresponds to a period of time in which acceleration starts and/or to a period of time just before motion of the sensor ends).

According to some embodiments, and as shown in reference **220**, operation **205** and **210** can be repeated, and in particular, a plurality of times.

15 Since acquisition of the images is performed while the camera has a static orientation towards a target, and while the sensor is static relative to the camera, smearing effect can be reduced and even cancelled. As a consequence, integration time (during which photons are collected by the sensor of the camera) can be increased, without blurring the image. In some embodiments, integration time has a magnitude of
20 tens of seconds.

Attention is now drawn to **Fig. 3D** which provides an iterative method of acquiring images of a plurality of scenes. Non-limitative illustrations of this iterative method are provided in **Figs. 3E to 3L**.

An objective of the mission is to acquire a plurality of scenes, by each pixel
25 band of the sensor. The scenes can comprise e.g. scenes located on Earth, which can be adjacent, or can be separated by a certain distance.

The method comprises (operation **300**), while a line of sight of the camera is maintained (e.g. by the satellite, or using the various methods described beforehand) fixedly oriented towards a target of a current scene SC_i (at the beginning of the mission,
30 $i=1$), controlling the camera to acquire, by each of one or more pixel bands of the sensor located at a current position relative to the camera, an image of a fraction of scene SC_i .

The method can comprise sending (operation **305**) a command to the actuator to move the sensor relative to the camera along at least one direction, from a current position to a new position assigned to the sensor.

In some embodiments, the sensor includes a plurality of pixel bands each having a similar (or different) width, and the processing unit is configured to move the sensor relative to the camera along a distance substantially equal (or smaller) to this width.

Once the sensor has reached its new position, each pixel band can therefore acquire
5 (operation **310**) a new fraction of current scene SC_i . As mentioned above with respect to **Figs. 3A to 3C**, acquisition of the image is performed (only or mainly) while the sensor is static relative to the camera.

In some cases, one or more of the pixel bands can acquire a fraction of the next scene SC_{i+1} (for example if the next SC_{i+1} is adjacent to the current scene SC_i and the
10 sensor has already reached the border between the two scenes SC_i/SC_{i+1}). This is visible in the non-limitative example of **Fig. 3K**, in which the line of sight of the camera is oriented towards the first scene **385**, and pixel band **350₁** is already acquiring fraction **386₁** of the next scene **386**.

In some cases, although the line of sight is oriented towards current scene SC_i , one
15 or more of the pixel bands can acquire a fraction of previous scene SC_{i-1} (for example, if the camera is oriented towards a target of scene SC_i which is located near the border between current scene SC_i and past scene SC_{i-1}). This is visible in the non-limitative example of **Fig. 3L**, in which the line of sight is oriented towards a target **386₂** of the second scene **386**. In this position, pixel band **350₃** is acquiring fraction **385_s** of the
20 previous scene **385**.

The method can comprise repeating operations **305** and **310** while the line of sight of the camera is oriented towards scene SC_i (see reference **320**), so as to acquire, by each of the pixel bands of the sensor, most or all of scene SC_i .

After a period of time (depending e.g. on the velocity of the satellite or of the
25 airborne, its trajectory or orbit, etc.) the line of sight of the camera is oriented towards a new scene SC_{i+1} .

This can be due to the fact that the scanning vehicle (e.g. satellite or airborne) is moving, and therefore, after a period of time, the line of sight will necessarily change its direction and point towards another portion of Earth. Therefore, the new scene SC_{i+1}
30 corresponds to the next scene of interest located on the route of the satellite or airborne.

This can be due also to the fact an orientation of the satellite or airborne is controlled so that the line of sight is oriented towards a new scene. For example, an agile satellite can be controlled so that the line of sight is oriented towards a new scene although this new scene is not located on the route of the satellite.

The method can include maintaining line of sight of the camera towards a target of the new scene SC_{i+1} (operation **300**, in which i has been incremented by one, as shown in reference **330**).

5 While the camera is pointing fixedly towards this new scene SC_{i+1} , the method can comprise performing again operations **301**, **305**, **310** and **320**.

In some embodiments, while the line of sight is switching from its past orientation towards scene SC_i to its new orientation towards scene SC_{i+1} , the method can comprise moving back the sensor towards its original position (relative to the camera) at which it started for scene SC_i . This is however not mandatory. From this original position, the
10 sensor can then acquire an image and be moved again relative to the camera, as explained in operations **301** and **305**.

The method can be repeated for a plurality of scenes SC_i , until the requested scenes have been acquired.

In some embodiments, the method is repeated until each pixel band of the sensor
15 of the camera gradually acquires an image of each a plurality of scenes SC_i as a whole.

As a consequence, if each pixel band acquires images in a different spectral range, an image of each scene can be formed in each spectral range. This can be obtained by aggregating, e.g. by a processing unit, for each pixel band, each fraction that it has acquired from a given scene, thereby forming a full image of the given scene in the spectral range
20 of this pixel band.

Attention is drawn to the example of **Fig. 3E**, which provides an example of the method of **Fig. 3D**, in the case of two scenes **385**, **386**. This is not limitative and the method applies to more than two scenes. The scenes are separated by a distance.

Fig. 3E depicts a sensor **330** (equivalent to sensor **130**) of a camera **380**. The
25 camera can be mounted on a scanning vehicle or an imager (reference **375**). A light of sight **390** the camera **380** is maintained oriented towards a fixed portion (target) of the first scene **385** on Earth. In this example, the line of sight **390** is fixedly oriented towards portion **385₃** of the first scene **385**. If the camera **380** is on a scanning vehicle, the line of sight of the camera **380** is maintained fixedly oriented during motion of the scanning
30 vehicle (for a satellite, it follows an orbital motion around Earth). It will now be referred for this example to a satellite, but as mentioned, this is not limitative.

In its first position relative to the camera **380** (see **Fig. 3E**), sensor **330** acquires only a fraction of the scene **385**. In particular, pixel band **350₁** acquires only fraction **385₁** of scene **385**.

As explained in **Figs. 2** and **3D**, a command can be sent to actuator **360**, in order to translate position of sensor **330** relative to the camera **380** (and to the satellite or airborne **375**) according to at least one direction. This corresponds to period of time PT_1 in **Fig. 3A**.

5 The direction which is selected to translate sensor **330** depends on the portion of the scene that needs to be observed. This direction can be, in some embodiments, parallel to the main direction of motion of the satellite or airborne, or in other embodiments, orthogonal to this main direction of motion. This is however not limitative, and in some embodiments, the direction of translation can be different from
10 or uncorrelated to the direction of motion of the satellite or airborne.

According to some embodiments, while a line of sight of the camera is maintained fixedly oriented towards a target of a scene, a direction of a motion of the sensor **330** relative to the camera is not opposite to a direction of a motion of the scanning vehicle (e.g. satellite **375**).

15 Once the sensor **330** has reached its new position shown in **Fig. 3F** (motion of the sensor **330** corresponds to period of time PT_1 in **Fig. 3A**), a command can be sent to the camera **380** to acquire again an image of the scene. Image acquisition corresponds to period of time PT_3 in **Figs. 3B** or **3C**. As mentioned above, according to some embodiments (see **Fig. 3B**), image acquisition is performed only if the sensor **330** has
20 reached its new position and is now static relative to the camera **380**.

Since a translation of the sensor **330** has been performed, sensor **330** can now acquire another fraction of the scene **385**.

In particular, (see **Fig. 3F**):

- pixel band **350₁** acquires now only fraction **385₂** of scene **385**; and
- 25 - pixel band **350₂** acquires now only fraction **385₁** of scene **485**.

This process can be repeated again. As shown in **Fig. 3G**, another translation of sensor **330** relative to vehicle **380** can be performed. Therefore:

- pixel band **350₁** acquires now only fraction **385₃** of scene **385**;
- pixel band **350₂** acquires now only fraction **385₂** of scene **385**; and
- 30 - pixel band **350₃** acquires now only fraction **385₁** of scene **385**.

This process can be repeated again, until each pixel band of the sensor has acquired each fraction **385₁** to **385₅** of the scene **385**. The last position of the sensor relative to the camera for acquiring this scene **385** is shown in **Fig. 3H**.

During the period of time corresponding to **Figs. 3E to 3H**, the line of sight of the camera was oriented towards portion **385₃** of the first scene **385** (e.g. while the satellite or airborne **375** was in motion).

In the time period between **Figs. 3H and 3I**, the orientation of the line of sight
5 **390** changes (e.g. due to motion of satellite or airborne **375**, and/or due to a modification of an orientation of the satellite or airborne). According to some embodiments, during this time period, the sensor can be moved back to its original position relative to the camera (its original position corresponds to **Fig. 3E**).

Alternatively, it is possible to maintain the sensor **330** at its last position relative
10 to the camera (as illustrated in **Fig. 3J**), and therefore, pixel band **350₃** will acquire fraction **386₅** of the second scene **386**. The other fractions of the scene **386** can be acquired by each pixel band by moving the sensor **330** relative to the camera in a direction **399** opposite to the direction used for the first scene.

As visible in **Fig. 3I**, line of sight **390** of camera **380** is oriented towards portion
15 **386₃** of the second scene **386**.

In **Fig. 3I**, pixel band **350₁** acquires now only fraction **386₁** of scene **386**.

The process which was performed for the first scene **385** (as depicted is **Figs. 3E to 3H**) is now repeated similarly for the second scene **386**.

As a consequence, each pixel band **350₁** to **350₃** of the sensor **350** acquires each
20 fraction **386₁** to **386₅** of the second scene **386**.

The last position of the sensor **350** relative of the camera for the second scene **386** is illustrated in **Fig. 3K** (in case acquisition of the second scene **386** has started as depicted in **Fig. 3I**).

By inducing a relative motion of the sensor **330** with respect to the camera **380**,
25 while the camera has a fixed line of sight, acquisition of different fractions of the scene by each of the pixel bands **350₁** to **350₃** of the sensor **330** is obtained, which could not be acquired without this relative motion.

In addition, according to some embodiments, since most of (or all of) image acquisition is performed during a period of time in which the sensor is fixed relative to
30 the camera and to the scene (and to the airborne or satellite, if the camera is fixed relative to the airborne or satellite), smearing effect is reduced, or even cancelled.

A possible application of the method described above can include acquiring image of a scene in different spectral ranges.

Assume that each pixel band **350₁** to **350₃** is configured to acquire an image in a different spectral range, respectively $[\lambda_1]$, $[\lambda_2]$, $[\lambda_3]$.

With the process described above, each fraction of the scene(s) will be acquired in each of these spectral ranges. Therefore, a full image of the scene(s) can be obtained
5 (by aggregating the different images acquired by each pixel band) in each of these spectral ranges.

Attention is now drawn to **Fig. 3L**. In some embodiments, and as depicted in **Fig. 3L**, the two scenes **385**, **386** can be adjacent, or close one to the other. Therefore, when implementing the method of **Fig. 3D**, it can appear at some stage that although
10 the line of sight of the camera is oriented towards a fixed target of the first scene **385**, one or more pixel bands (in this example pixel band **350₁**) of the sensor is already acquiring a fraction of the second scene **386**.

Attention is now drawn to **Fig. 3M**. In some embodiments, and as depicted in **Fig. 3M**, the two scenes **385**, **386** can be adjacent, or close one to the other. Therefore, when implementing the method of **Fig. 3D**, it can appear at some stage that although
15 the line of sight of the camera is oriented towards a fixed target of the second scene **386**, one or more pixel bands (in this example pixel band **350₃**) of the sensor are still acquiring a fraction of the first scene **385**.

Another application of the methods described beforehand is illustrated in **Fig.**
20 **4**.

As shown, a sensor **430** (equivalent to sensor **130**) of a camera **480** is mounted on platform **475** which can be a scanning vehicle (e.g. satellite or airborne) or a scanning imager on ground. A light of sight (LOS) **490** of the camera **480** is maintained oriented towards a fixed portion (target) of the first scene **485** on Earth, using the various
25 methods described above. In this example, the line of sight **490** is oriented towards portion **485₄** of a scene **485**.

In this example, the sensor **430** comprises a single pixel band **450** (this is however not limitative). The pixel band **450** has a field of view which is smaller than the scene **485** to be acquired, and therefore, acquires only a fraction (at this period of
30 time, fraction **485₁**) of the scene **485**.

In order to acquire the whole scene **485**, a command can be sent to actuator **460**, in order to translate position of sensor **430** relative to the camera **480** (and to the airborne or satellite **475**) according to at least one direction.

Once the sensor **430** has reached its new position (see **Fig. 4A**), a command can be sent to the camera **480** to acquire again an image of the scene. Image acquisition corresponds to period of time PT_3 in **Figs. 3B** or **3C**. As mentioned above, according to some embodiments (see **Fig. 3B**), image acquisition is performed only if the sensor

5 **430** has reached its new position and is now static relative to the camera **480**.

Since a translation of the sensor **430** has been performed, sensor **430** can now acquire another fraction **485₂** of the scene **485**.

This process can be repeated, until the whole scene **485** is acquired by the sensor **430**. The last position of the sensor **430** is illustrated in **Fig. 4B**, in which the sensor

10 **430** acquires the last portion **485₆** of the scene **485**.

Over time, line of sight **490** will be oriented towards a target of another scene, which can be acquired similarly by sensor **430**.

As mentioned above, smearing can be reduced and even cancelled, since sensor **430** acquires an image only when the camera is oriented towards a fixed target of a scene, and when the sensor **430** is fixed (after its translation) relative to the camera.

15

Embodiments of the presently disclosed subject matter are not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the presently disclosed subject matter as described herein.

The invention contemplates a computer program being readable by a computer for executing one or more methods of the invention. The invention further contemplates a machine-readable memory tangibly embodying a program of instructions executable by the machine for executing one or more methods of the invention.

20

It is to be noted that the various features described in the various embodiments may be combined according to all possible technical combinations.

25

It is to be understood that the invention is not limited in its application to the details set forth in the description contained herein or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Hence, it is to be understood that the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting. As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the presently disclosed subject matter.

30

Those skilled in the art will readily appreciate that various modifications and changes can be applied to the embodiments of the invention as hereinbefore described without departing from its scope, defined in and by the appended claims.