

[Document Name] Description

[Title of Invention] UNMANNED AERIAL VEHICLE, AND METHOD FOR
USING SAME

5 [Technical Field]

[0001]

The present invention relates to an unmanned aerial vehicle, and a
method using this. In particular, the present invention is related to an
unmanned aerial vehicle for a flight with taking (capturing) images inside a
10 closed-type space (or a confined space) such as inside a tubular space and
inside a rectangular space, and the present invention is related to a method
using the unmanned aerial vehicle.

[Background Art]

15 [0002]

The durable years (service life) of a sewerage pipe line is deemed to
be approximately 50 years, and it is assumed that the number of facilities
which will reach the durable years will rapidly increase hereafter. For
efficient maintenance and management, it is necessary to comprehend the
20 states of sewerage pipe lines.

[0003]

Conventionally, as inspection methods of the state of a sewerage pipe
line, methods such as a method in which an investigator goes underground
into the pipe and inspects directly by visual observation, a method of
25 positioning, inside the pipe, a television camera which is connected to above
the ground via a cable and of taking images, and a method of positioning,
inside the pipe, a television camera which is connected to above the ground
via a cable and which is mounted on a self-propelled car and of taking images
while running (travelling), have been used. However, in the method by
30 direct visual observation by an investigator, there are various problems such

as a risk of influence on a human body via generation of poisonous gas inside the sewerage pipe line and a risk by inundation when a rainfall rapidly occurs. And, also in the method of positioning a television camera inside the pipe, there are problems such as an sufficient inspection speed being not
5 obtained, and difficulty in controlling the car when the water level inside the sewerage pipe line rises.

[Summary]

[0004]

10 Therefore, the present disclosure aims to provide a method, which does not require direct visual observation by an investigator and which has good efficiency, of taking images inside a closed-type space (or a confined space) such as a culvert (a waterway provided underground).

15 [0005]

 In order to solve the above problem (achieve the above aim), the present disclosure provides an unmanned aerial vehicle having at least four rotary wings (rotors), a drive device that drives the rotary wings, a control signal generation circuit that generates a control signal for causing the drive
20 device to drive the rotary wings, and an imaging camera, wherein the unmanned aerial vehicle is configured to fly inside a closed-type space (confined space) with driving the rotary wings while taking (capturing) images inside the closed-type space by means of the imaging camera.

[0005a]

25 In a first aspect, the present disclosure provides an unmanned aerial vehicle comprising: a frame having a shape elongated along the forward direction; four rotary wings consisting of a first pair of rotary wings and a second pair of rotary wings, wherein the first pair of rotary wings is a pair of

two rotary wings positioned on the front-half side of the frame and the second pair of rotary wings is a pair of two rotary wings positioned on the back-half side of the frame, and wherein the four rotary wings are positioned inside the frame; a drive device that drives the four rotary wings; a control
5 signal generation circuit that generates a control signal for causing the drive device to drive the four rotary wings, wherein the control signal generation circuit is stored in a waterproof case and the waterproof case is positioned between the first pair of rotary wings and the second pair of rotary wings; and an imaging camera, wherein the unmanned aerial vehicle is configured
10 to fly inside a tubular closed-type space extending in a direction other than a vertical direction with driving the four rotary wings while taking images inside the closed-type space by means of the imaging camera, wherein the four rotary wings, the drive device, the waterproof case, and the imaging camera are integrated using the frame, wherein an upper surface of the
15 frame defines four apertures that correspond respectively with one of the four rotary wings, and each of the four apertures is partly covered by the frame.

[0006]

It is possible to further provide the above unmanned aerial vehicle
20 with a member for preceding impact (collision) which is for causing an impact on a boundary surface in advance when the unmanned aerial vehicle impacts on (collides with) the boundary surface of the closed-type space.

[0007]

It is possible to further configure the above unmanned aerial vehicle so that, the member for preceding impact is positioned at the side of one edge of the unmanned aerial vehicle and, when the unmanned aerial vehicle
5 impacts on the boundary surface while flying inside the closed-type space with the side of the one edge as the forward side, the member for preceding impact is configured to impact on the boundary surface on the forward side ahead of the position of the center of gravity (centroid) of the unmanned aerial vehicle.

10 [0008]

It is possible to further configure the above unmanned aerial vehicle so that the control signal includes an attitude control signal, the attitude control signal causes the drive device to drive the rotary wings, and, when the unmanned aerial vehicle is tilted, the attitude of the unmanned aerial
15 vehicle is controlled by reducing the number of rotations (rotational speed) of one or some of the rotary wings.

[0009]

It is possible to further configure the above unmanned aerial vehicle so that the drive device includes at least four motors which provide the
20 respective rotary wings with motive powers, respectively, and each of the motors provides the rotary wing with motive power at a position with a higher gravitational potential than the rotary wing which receives motive power from the each motor.

[0010]

25 It is possible to further configure the above unmanned aerial vehicle so that it further includes a thrust generation propeller and propels by rotations of the thrust generation propeller while floating by rotations of the at least four rotary wings.

[0011]

30 It is possible to further configure the above unmanned aerial vehicle

so that it further includes a direction of travel imaging camera and a direction of travel imaging data transmitter, and that the unmanned aerial vehicle flies inside the closed-type space while taking images of the direction of travel inside the closed-type space by means of the direction of travel
5 imaging camera and while transmitting, to the outside, the obtained direction of travel imaging data from the direction of travel imaging data transmitter.

[0012]

In addition, the present disclosure provides a method of causing a
10 unmanned aerial vehicle having at least four rotary wings (rotors), a drive device that drives the rotary wings, a control signal generation circuit that generates a control signal for causing the drive device to drive the rotary wings, and an imaging camera, to fly inside a closed-type space (confined space) with driving the rotary wings while taking (capturing) images inside
15 the closed-type space by means of the imaging camera.

[0012a]

In a second aspect, the present disclosure provides a method of causing an unmanned aerial vehicle having: a frame having a shape elongated along the forward directions; four rotary wings consisting of a first
20 pair of rotary wings and a second pair of rotary wings, wherein the first pair of rotary wings is a pair of two rotary wings positioned on the front-half side of the frame and the second pair of rotary wings is a pair of two rotary wings positioned on the back-half side of the frame, and wherein the four rotary wings are positioned inside the frame, a drive device that drives the four
25 rotary wings, a control signal generation circuit that generates a control signal for causing the drive device to drive the four rotary wings, wherein the control signal generation circuit is stored in a waterproof case and the waterproof case is positioned between the first pair of rotary wings and the second pair of rotary wings; and an imaging camera, wherein the four rotary
30 wings, the drive device, the waterproof case, and the imaging camera are

integrated using the frame, wherein an upper surface of the frame defines four apertures that correspond respectively with one of the four rotary wings, and each of the four apertures is partly covered by the; to fly inside a tubular closed-type space extending in a direction other than a vertical direction with
5 driving the four rotary wings while taking images inside the tubular closed-type space by means of the imaging camera.

[0013]

By the present disclosure, taking of images inside the closed-type space with higher safety and without necessity of going underground by an
10 investigator, becomes possible. In addition, in comparison to a self-propelled car, the unmanned aerial vehicle does not tend to impair its mobility even in a case where there is water inside the closed-type space, thus more efficient imaging becomes possible.

15 [Brief Description of Drawings]

[0014]

[Figure 1A] A perspective view (oblique drawing) of an unmanned aerial vehicle as one embodiment of the present invention

[Figure 1B] A figure showing the unmanned aerial vehicle of Figure 1A

from the positive (forward) z-direction

[Figure 1C] A figure showing the unmanned aerial vehicle of Figure 1A from the positive (forward) y-direction

[Figure 1D] A perspective view showing the unmanned aerial vehicle of Figure 1A from the backward side of the forward direction

[Figure 2A] A perspective view showing the positional relationship between a rotor and a motor member in a comparative example

[Figure 2B] A figure showing the rotor and the motor member in Figure 2A from the positive x-direction

10 [Figure 2C] A figure showing the cross section obtained by cutting the motor member in Figure 2A on the A-A surface in Figure 2B and showing the respective motor members

[Figure 3] A perspective view showing the positional relationship between a rotor and a motor member in this embodiment

15 [Figure 4] A block diagram showing the functions and configurations of the unmanned aerial vehicle in Figure 1A

[Figure 5] A figure showing the structure of a sewerage pipe line facility in which the unmanned aerial vehicle in Figure 1A can be caused to fly

[Figure 6] A figure showing the unmanned aerial vehicle in Figure 1A flying inside the tubular space in the sewerage pipe line facility in Figure 5

20 [Figure 7] A figure showing the state (situation) of the unmanned aerial vehicle impacting on the inner wall of the sewerage pipe line during a flight shown in Figure 6

[Figure 8] A figure showing the state of the unmanned aerial vehicle in Figure 1A rotating about the x-axis (rolling rotation) and being tilted

[Figure 9] A figure showing an example of an image inside of the sewerage pipe line to be taken by means of the forward camera

[Description of Embodiments]

30 [0015]

In the following, an unmanned aerial vehicle and a method using this as one embodiment of the present invention will be described with referring to the figures. However, it is noted that the unmanned aerial vehicle and the method using this of the present invention are not limited to particular aspects explained in the following, but they can be changed appropriately within the scope of the present invention. For example, the unmanned aerial vehicle of the present invention is not required to be an autonomous flying type unmanned aerial vehicle. The functions and configurations of the unmanned aerial vehicle can also be arbitrarily made and they are not limited to those in Figure 4, as long as similar actions are possible. For example, actions to be performed by a plurality of components can be performed by a single component, such as by integrating the functions of the communication circuit into the main operation circuit, or actions to be performed by a single component shown in figures can be performed by a plurality of components such as by distributing the functions of the main operation circuit to a plurality of operation circuits. The autonomous control program for the unmanned aerial vehicle can be stored in a memory (recording) device such as a hard disk drive, read out and executed by the main operation circuit (the autonomous control program shown in figures can be divided (broken-down) into a plurality of program modules, and other arbitrary program can be executed by a main operation circuit etc.), or similar actions can be performed by an integration type (built-in type) system using a microcomputer etc. The unmanned aerial vehicle of the present invention is not required to have all components shown in the following embodiments (for example, when the propulsion of the unmanned aerial vehicle is controlled by controlling of the rotors 9-12 in Figure 1B, it is not required to have a thrust generation propeller 21. If the unmanned aerial vehicle is caused to fly completely via control from outside without autonomous control, it is not required to have an autonomous control program or various databases.), and the method of the present invention is

not required to have all shown method steps. The rotary wings for floating the unmanned aerial vehicles can be four or more arbitrary rotary wings, and they are not limited to four rotors 9-12 shown in Figure 1B etc. The propeller for generating thrust can be an arbitrary propeller and it is not limited to the thrust generation propeller 21 shown in Figure 1D etc. The air-frame (body) size of the unmanned aerial vehicle can be arbitrary defined. In addition, the closed-type space (confined space) is not required to be completely closed. It is sufficient if the closed-type space is a space which is at least partially closed to at least partially restrict the flight of the unmanned aerial vehicle. For example, also a tubular space in a sewerage pipe line connected to the outside via a man-hole as shown in the following embodiment is a closed-type space.

[0016]

Configuration of Unmanned Aerial Vehicle

The appearance of an unmanned aerial vehicle as one embodiment of the present invention is shown in Figures 1A to 1D. Figure 1A is a perspective view, Figure 1B is a figure from the positive z-direction of Figure 1A, Figure 1C is a figure from the positive y-direction, and Figure 1D is a perspective view from the backward side of the forward direction (members for preceding impact are omitted.). The unmanned aerial vehicle 1 is designed to have a size with the overall width (the width in the y-direction in Figure 1A) of approximately 250mm, the overall length (the width in the x-direction in Figure 1A) of approximately 550mm in order to enable to fly in a closed-type space with the diameter (aperture) of approximately 400mm. The unmanned aerial vehicle 1 has a main body part 2 (stored in a waterproof case 3), five motors 13 to 17 driving by control signals from the main body part 2 (for motors 14, 16, see Figure 4), four rotors (rotary wings) 9 to 12 rotating by driving of the respective motors 13 to 16 to float the unmanned aerial vehicle 1 (Adjacent rotors rotate reversely to each other. For example, rotors 9, 12 rotate clockwise when seen from the positive

z-direction, and rotors 10, 11 rotate counter-clockwise when seen from the positive z-direction.), a thrust generation propeller 21 which generates a thrust of the unmanned aerial vehicle 1 by rotating by driving of the motor 17, an investigation camera 18, a forward camera 19, and an ultrasonic sensor 20. The respective components are integrated using a frame 4, and four members for preceding impact 5 to 8 are attached to the frame 4. [0017]

The members for preceding impact 5 to 8 are constructed as wheels, and they are members for preceding impacts when the unmanned aerial vehicle 1 impacts on the boundary surface of the closed-type space such as a wall surface of a sewerage pipe line. As shown in Figures 1A to 1C, the members for preceding impact 5 to 8 are preferably positioned on the forward (positive x-direction in Figure 1A) side relative to the center of gravity 22 of the unmanned aerial vehicle 1. By applying such the positions, the members for preceding impact 5 to 8 impact on (collide with) the boundary surface of the closed-type space on the forward side relative to the center of gravity 22, thus the direction of travelling of the unmanned aerial vehicle 1 at that time can be stabilized on the forward side. The members for preceding impacts can be constructed as members other than wheels. For example, it is possible to fix etc. spherical members for preceding impacts at the upper part on the forward side of the unmanned aerial vehicle 1. [0018]

The investigation camera 18 is a camera for taking still images or moving images (video) while the unmanned aerial vehicle 1 is flying inside the closed-type space, and in one example, it is possible to use a commercially available camera such as GoPro session (Tajima motor corporation). The forward camera 19 is a camera for taking still images or moving images in the direction of travel while the unmanned aerial vehicle 1 is flying inside the closed-type space, data of the taken still images or moving images are transmitted to an external device (such as a computer provided

with a display) at any time as required, and a navigator (operator) can navigates (operates) the unmanned aerial vehicle 1 while checking it. The ultrasonic sensor 20 is a sensor for detecting blocking objects etc. in the forward direction, and the ultrasonic sensor 20 can measure the distance
5 from the blocking objects etc. by transmitting ultrasonic wave in the direction of travel, while the unmanned aerial vehicle 1 is flying inside the closed-type space, and by receiving the reflected wave.

[0019]

As shown in Figure 1C, motors 13, 15 are positioned respectively
10 above the rotors 9, 11 (on positions with higher gravitational potential) and the motors 13, 15 are configured to drive the rotors 9, 11 respectively. Also the motors 14, 16 (see Figure 4) are positioned respectively above the rotors 10, 12 similarly and the motors 14, 16 are configured to drive these rotors respectively. The advantage by employing such the configuration will be
15 described with comparing to a comparative example in which the motors are positioned under the rotors as shown in Figures 2A to 2C. In this regard, it is noted that the unmanned aerial vehicle and the method using this of the present invention can be embodied even when the positional relationship between the rotors and motors in accordance with that comparative example
20 is employed.

[0020]

Figure 2A is a perspective view showing the positional relationship between a rotor and a motor member in a comparative example, Figure 2B is a figure showing the rotor and the motor member in Figure 2A from the
25 positive x-direction in Figure 2A, and Figure 2C is a figure showing the cross section obtained by cutting the motor member in Figure 2A on the A-A surface in Figure 2B and showing the respective motor members. Rotors 9, 10, 11, 12 are fixed (see Figure 2B) to rod-like projection portions of motor members 23A (see Figure 2C), and they rotate about the rod-like projection
30 portions as the rotation axes. Rotors 9, 10, 11, 12 are subjected to (receive)

force in the arrow direction in Figure 2A (positive z-direction) by rotating, and pull the motor members 23 A in the same direction. As shown in Figure 2C, a motor member 23A and a motor member 23 B are fitted to each other, but they are not adhered. Therefore, when the motor member 23A is pulled
5 in the positive z-direction, there is a risk that the motor member 23 A escapes from the motor member 23B. In order to avoid that escaping, a motor member 23C is used as a fastening tool in the configuration of the comparative example (see Figures 2B, 2C). As shown in Figure 2C, it is possible to avoid the escaping of the motor member 23A from the motor
10 member 23B by fitting the motor member 23C (after the motor member 23A and the motor member 23B are fitted to each other) to the groove part 23A-1 provided on the motor member 23A. However, it is necessary to release the motor member 23C at the time of maintenance of motors.

[0021]

15 A perspective view of Figure 3 shows the positional relationship between a rotor and a motor member in this embodiment. It is different from the comparative example in that rotors 9, 10, 11, 12 are positioned under the motor members 23A, 23B and in that no motor member 23C is used, and the remaining configurations are similar to the comparative
20 example. Rotors 9, 10, 11, 12 are fixed (see Figure 2B) to rod-like projection portions of motor members 23A (see Figure 2C), and they rotate about the rod-like projection portions as the rotation axes. Rotors 9, 10, 11, 12 are subjected to (receive) force in the arrow direction in Figure 3 (positive z-direction) by rotating, and push the motor members 23 A in the same
25 direction. By this, a motor member 23A is pushed onto a motor member 23B, thus it is not necessary to prevent the motor member 23A from escaping from the motor member 23B. Therefore, the motor member 23C becomes unnecessary in the configuration of Figure 3, thus maintenance of motors become easier.

30 [0022]

Figure 4 is a block diagram showing the functions and configurations of the unmanned aerial vehicle in Figure 1A. The main body 2 of the unmanned aerial vehicle 1 has:

a main operation circuit 24a which is configured by a processor, a tentative (volatile) memory, etc. and which performs various operations;

a signal conversion (transformation) circuit 24b which performs processing such as conversion of control command value data obtained by the operations by the main operation circuit 24a into pulse signals for the motors 13 to 17 where the signal conversion circuit 24b is configured by a processor, a tentative memory, etc. (an operation circuit including the main operation circuit 24a and the signal conversion circuit 24b is referred to as a control signal generation circuit 25.);

speed controllers (ESC: Electric Speed Controller) 26 to 30 which convert the pulse signals generated in the control signal generation circuit 25 into driving electric currents for the motors 13 to 17;

a communication antenna 31 and a communication circuit 32 in charge of transmitting/receiving of various data signals to/from the outside;

a sensor part 33 including various sensors such as a GPS (Global Positioning System) sensor, an attitude sensor, an altitude sensor, an orientation (azimuth) sensor;

a memory (recording) apparatus 35 configured by a memory device such as a hard disk drive recording an autonomous flight program 34a, various databases 34b etc.; and

a power source system 36 including a battery device such as a lithium polymer battery and a lithium ion battery, and electric power distribution system for the respective elements.

[0023]

In addition to the above, the unmanned aerial vehicle 1 can have arbitrary functional parts, information, etc., in accordance with the functions or intended uses. As an example, in a case where the unmanned aerial

vehicle 1 performs an autonomous flight according to a flight plan, the memory apparatus 35 records flight plan information as data indicating a flight plan as some rules which should be followed during the flight such as: a flight plan path (route) as a set of the starting position of the flight, the destination position, and the checkpoint positions (latitudes, longitudes, altitudes) which should be gone through between the departure at the starting position and the arrival at the destination position; speed restrictions; and altitude restrictions. The unmanned aerial vehicle 1 flies in accordance with the flight plan when the flight plan information is read by the main operation circuit 24a and the autonomous control program 34a is executed by the main operation circuit 24a. In particular, the current (present) position, velocity, etc. of the unmanned aerial vehicle 1 are determined from information obtained at the various sensors in the sensor part 33, and the control command values for the rotors 9-12 and the thrust generation propeller 21 are calculated (operated) at the main operation circuit 24a by comparison to the target values of the flight plan paths, speed restrictions, altitude restrictions, etc. defined in the flight plan. Further, the data indicating the control command values are converted into the pulse signals at the signal conversion circuit 24b (generation of control signals) and sent to the speed controllers 26 to 30, the speed controllers 26 to 30 respectively convert the pulse signals into driving electric currents and output them to the motors 13 to 17, thus control driving of the motors 13 to 17 to control the rotation speeds etc. of the rotors 9 to 12 and the thrust generation propeller 21. Flight of the unmanned aerial vehicle 1 is controlled in this way. In an example, the numbers of rotations (rotational speeds) of the rotors 9 to 12 are increased (risen) in response to control commands for increasing the altitude of the unmanned aerial vehicle 1 (the number of rotations are decreased when decreasing the altitude), the number of rotations of the thrust generation propeller 21 is increased in response to control commands for accelerating the unmanned aerial vehicle 1

in the forward direction (positive x-direction in Figure 1A) (the number of rotations is decreased when decelerating), and the numbers of rotations of the rotors 10, 12 are decreased while the numbers of rotations of the rotors 9, 11 are maintained (kept) in response to control commands for tilting the unmanned aerial vehicle 1 by rolling rotation about the x-axis in Figure 1A (counter-clockwise when seen from the positive x-direction). Controls such as the above are performed. In this regard, the acceleration (deceleration) in the forward direction of the unmanned aerial vehicle 1 can be performed also by controlling the number of rotations of the rotors 9 to 12 such as by reducing the number of rotations of the rotors 9, 10 while increasing the number of rotations of the rotors 11, 12 (oppositely controlled when decelerating). It is also possible to make the unmanned aerial vehicle 1 fly without using the thrust generation propeller 21. In this regard, when the unmanned aerial vehicle 1 is used for the intended use of making the unmanned aerial vehicle 1 fly inside the closed-type space as described below, simplified controls such as controls where, the numbers of rotations of all the rotors 9 to 12 are kept at the same number (only controls for equally increasing or decreasing the numbers of rotations of all the four rotors 9 to 12 are performed) to float/land (land on the ground or land on water) the unmanned aerial vehicle 1 while controlling the number of rotations and rotational direction of the thrust generation propeller 21 to control the velocity in the forward direction (positive x-direction in Figure 1A), are also possible. Flight record information such as the flight path which the unmanned aerial vehicle 1 actually flew (went through) (such as air-frame positions of the unmanned aerial vehicle 1 at respective times) and various sensor data is recorded in the various databases 34b during the flight at any time as required.

[0024]

Examples of commercially available autonomous flight-type unmanned aerial vehicles include: Mini Surveyor MS-06LA (Autonomous

Control Systems Laboratory Ltd.); Snap (Vantage Robotics); AR. Drone 2.0 (Parrot); Bebop Drone (Parrot) and the like.

[0025]

In this regard, when the unmanned aerial vehicle 1 flies under
5 control from outside (under external control), the unmanned aerial vehicle 1
receives data indicating control command values (received from a controller
device of the navigator etc.) via the communication antenna 31 and the
communication circuit 32, converts the data into pulse signals at the signal
conversion circuit 24b (generation of control signals), and hereinafter
10 similarly performs flight control by controlling the rotation speeds of the
rotors 9 to 12 and the thrust generation propeller 21 using the speed
controllers 26 to 30 and the motors 13 to 17. Also even in this case,
partially autonomous control and control from the outside can be combined,
such as by calculating the command values for attitude control by comparing
15 etc. the data from the attitude sensor and the target values of the attitude to
perform the attitude control via reading data, at the main operation circuit
24a, indicating attitude information of the unmanned aerial vehicle 1
obtained from the attitude sensor (gyro-sensor, magnetic sensor) among the
various sensors in the sensor part 33, and via executing, at the main
20 operation circuit 24a, the autonomous control program 34a (in this case, the
final (definitive) control command values are calculated from data indicating
control command values received from the external controller etc. and data
indicating attitude control command values by executing, at the main
operation circuit 24a, the autonomous control program 34a. By converting,
25 at the signal conversion circuit 24b, data indicating those control command
values into pulse signals, control signals including attitude control signals
are generated.). In the flight with taking images described below, it is
assumed that the unmanned aerial vehicle 1 flies basically by control signals
from the external controller device etc., and it is assumed that only the
30 attitude is controlled in an autonomous fashion. However, it is also possible

to perform a similar flight with taking images even by an unmanned aerial vehicle 1 which performs completely autonomous flight or which performs flight completely under control from the outside.

[0026]

5 Flight with Taking Images inside the Closed-Type Space by the Unmanned Aerial Vehicle

In the following, as an example of flight with taking images inside the closed-type space by the unmanned aerial vehicle 1, a flight with taking images in a sewerage pipe line will be described using Figures 5 to 9.

10 [0027]

Figure 5 shows the structure of a sewerage pipe line facility in which the unmanned aerial vehicle in Figure 1A can be caused to fly. A man-hole 38a provided on the ground surface 37 leads to (is connected to) the sewerage pipe line 39, and going in the right direction of Figure 5 in the sewerage pipe line 39 leads to (reaches) another man-hole 38b (The sewerage pipe line 39 is depicted with dividing the same at two intermediate positions in Figure 5, but this is just an expediential expression, and the actual sewerage pipe line 39 is formed as a continuous sewerage pipe line 39 longer than that depicted.). A boundary surface of the closed-type space is defined by an inner wall 40 of the sewerage pipe line 39, and there are connecting parts 41 in the sewerage pipe line 39 at predetermined intervals in the right direction of Figure 5.

[0028]

When performing a flight while taking pictures by the unmanned aerial vehicle 1 in the sewerage pipe line 39, the unmanned aerial vehicle 1 is firstly caused to enter the man-hole 38a and descend to the depth of the sewerage pipe line 39. In one example, the unmanned aerial vehicle 1 is caused to descend by providing a holding base at the edge of a pole of which the length is the same degree as the depth of the man-holes 38a, 39b, placing the unmanned aerial vehicle 1 on the holding base, and inserting the pole

into the man-hole 38a. When using an autonomous flight-type unmanned aerial vehicle 1, it is possible to: record the position of the man-hole 38a, the depth of the sewerage pipe line 39 etc. as the flight plan path in the memory apparatus 35 in advance; read, by the main operation circuit 24a, flight plan
5 information including data of the flight plan path; and execute, by the main operation circuit 24a, the autonomous control program 34a to cause the unmanned aerial vehicle 1 to autonomously fly to lead the unmanned aerial vehicle 1 to one edge of the sewerage pipe line 39 (the left edge of the sewerage pipe line 39 in Figure 5, and hereinafter as the starting position S
10 of the flight with taking images). Alternatively, it is also possible to transmit control signals from an external controller device to the unmanned aerial vehicle 1 and operate (navigate) the unmanned aerial vehicle 1 to lead the unmanned aerial vehicle 1 to the starting position S of the flight with taking images.

15 [0029]

The unmanned aerial vehicle 1 starts flight with taking images from the starting position S of the flight with taking images toward the right direction of Figure 5 (taking that direction as the positive x-direction of Figure 1A, namely the direction of travel) (Figure 6). In the case of manual
20 control from an external controller by an operator, the unmanned aerial vehicle 1 receives a control signal instructing to go forward, and takes still images or moving images in the sewerage pipe line 39 by means of the investigation camera 18 and the forward camera 19 while flying in the direction of travel. In this regard, water 42 usually exists in the sewerage
25 pipe line 39, the water level is changing at any time, and it is also possible to obtain force for floating by the water surface effect accompanying rotations of the rotors 9 to 12 (Even in a case where there is no water 42, it is possible to obtain a similar effect from the inner wall 40.).

[0030]

30 Data of still images or moving images taken by means of the

investigation camera 18 are stored in the internal (built-in) memory of the investigation camera 18. Data of still images or moving images taken by means of the forward camera 19 are stored in the internal memory of the forward camera 19 and transmitted, at any time as required, from the communication antenna 31 by means of the communication circuit 32 to an external computer of the operator. The operator displays, using the received data and on a display which the external computer has, the still images or moving images taken by the forward camera 19. The operator operates the unmanned aerial vehicle 1 by means of the external controller while checking the displayed still images or moving images. In one example, the unmanned aerial vehicle 1 is operated while the distance which the unmanned aerial vehicle 1 has passed through is comprehended taking the connecting parts 41 appearing in the displayed still images or moving images as marks.

[0031]

During the flight with taking images, the unmanned aerial vehicle 1 may impact on (collide with) the inner wall 40 of the sewerage pipe line 39 for some reasons such as problems in accuracy of manual control by means of the external controller and problems in accuracy of autonomous control of the attitude. The aspect (situation) in this case is shown in Figure 7. The attitude of the unmanned aerial vehicle 1 is corrupted for some reasons, and the unmanned aerial vehicle 1 impacts, at the upper part on the forward side of the air-frame, on the inner wall 40. However, the member for preceding impact 5 (see Figure 1A etc.) and the member for preceding impact 6 impact on the inner wall 40 in advance, and the unmanned aerial vehicle 1 continues to travel forwardly (in the arrow direction of Figure 7). Since the members for preceding impact 5 to 8 are configured as wheels in this embodiment, the members for preceding impact 5, 6 rotate while being in touch with the inner wall 40, as shown by the arrow A in Figure 7, and the unmanned aerial vehicle 1 travels like it is along the upper surface of the

inner wall 40. As another example, in a case where the members for preceding impact are fixed, as spherical members, on the upper part on the forward side of the unmanned aerial vehicle 1, the unmanned aerial vehicle bounds toward the direction shown by the arrow B in Figure 7 after the member for preceding impact of the unmanned aerial vehicle 1 impacts on the upper surface of the inner wall 40. Anyway, the unmanned aerial vehicle 1 can continue the flight forwardly. Even in a case where the unmanned aerial vehicle 1 impacts on a side surface of the inner wall 40, the unmanned aerial vehicle 1 can continue the flight forwardly by similar preceding impact by the member for preceding impact 7 or 8.

[0032]

During the flight with taking images, the unmanned aerial vehicle 1 may be tilted for some reasons, similarly such as problems in accuracy of manual control or autonomous attitude control. As an example, Figure 8 shows the state of the unmanned aerial vehicle 1 rotating about the x-axis in Figure 1A (rolling rotation) and being tilted. In order to recover the attitude of the air-frame to be flat (horizontal), it is assumed that the lower side of the air-frame (the side of positive y-direction) is lifted (elevated) by increasing the numbers of rotations of the rotors 9 and 11, but there is a risk that the air-frame is lifted and the unmanned aerial vehicle 1 impacts on the upper surface of the inner wall 40 in this case. Therefore, it is preferable to recover the attitude to be flat by making the higher side (the side of the negative y-direction) of the air-frame descend by reducing the numbers of rotations of the rotors 10 and 12. Such the attitude control is performed typically by reading data indicating the attitude information of the unmanned aerial vehicle 1 obtained from the attitude sensor as described above at the main operation circuit 24a and executing the autonomous control program 34a, but it is also possible to perform the attitude control by: transmitting control signals (control signals instructing to perform rolling rotation in the opposite direction relative to the tilt in Figure 8) indicating

the control command values of the attitude from the external controller device; receiving the control signals at the unmanned aerial vehicle 1; and executing the autonomous control program 34a at the main operation circuit 24a. With regard to tilt of the unmanned aerial vehicle 1 due to arbitrary rotations such as rotation about y-axis (pitch) and rotation about z-axis (yaw), it is preferable to recover the attitude similarly by reducing the number of rotations of one or some of the rotors.

[0033]

The flight with taking images ends by the unmanned aerial vehicle 1's arrival at the other edge of the sewerage pipe line 39 (the right edge in the sewerage pipe line 39 in Figure 5, and hereinafter as the end position G of the flight with taking images). The unmanned aerial vehicle 1 is retrieved by, for example, inserting the pole, the edge of which a holding base is provided, into the man-hole 38b, placing the unmanned aerial vehicle 1 on the holding base, and pulling it upward. It is also possible to pull up the unmanned aerial vehicle 1 from the end position G via autonomous flight similarly to the introduction into the start position S of the flight with taking images. The states of the sewerage pipe lines 39, the inner wall 40, etc. can be checked by removing the investigation camera 18 from the retrieved unmanned aerial vehicle 1 and watching the still images or moving images stored in the memory.

[0034]

Figure 9 shows an example of an image inside of the sewerage pipe line to be taken by means of the forward camera. It is assumed (expected) that similar images can be obtained via flight with taking images by the unmanned aerial vehicle 1 on which the forward camera 19 is provided. The operator can operate the unmanned aerial vehicle 1 by means of the external controller device while watching still images or moving images in first-person view taken by the forward camera 19 as shown in Figure 9. After the flight with taking images, the state of the sewerage pipe line 39

such as cracks in the inner wall 40 and dislocations of packings at the connecting parts 41 can be checked by removing the investigation camera 18 from the retrieved unmanned aerial vehicle 1 and watching still images or moving images stored in the memory.

5

[Industrial Applicability]

[0035]

The present invention can be utilized for flight with taking images in arbitrary closed-type spaces such as in water-supply pipe lines, sewerage
10 pipe lines, drainage ditches, cave passages, ducts, pipe shafts, and gas pipe lines.

[Reference Signs List]

[0036]

15	1	unmanned aerial vehicle
	2	main body part
	3	waterproof case
	4	frame
	5-8	member for preceding impact
20	9-12	rotor
	13-17	motor
	18	investigation camera
	19	forward camera
	20	ultrasonic sensor
25	21	thrust generation propeller
	22	center of gravity
	23A	motor member
	23B	motor member
	23C	motor member
30	23A-1	groove

	24a	main operation circuit
	24b	signal conversion circuit
	25	control signal generation circuit
	26-30	speed controller
5	31	communication antenna
	32	communication circuit
	33	various sensors
	34a	autonomous control program
	34b	various databases
10	35	memory apparatus
	36	power source system
	37	ground surface
	38a, b	man-hole
	39	sewerage pipe line
15	40	inner wall
	41	connecting part
	42	water

[Document Name] Claims

[Claim 1]

An unmanned aerial vehicle comprising:

a frame having a shape elongated along the forward direction;

5 four rotary wings consisting of a first pair of rotary wings and a second pair of rotary wings, wherein the first pair of rotary wings is a pair of two rotary wings positioned on the front-half side of the frame and the second pair of rotary wings is a pair of two rotary wings positioned on the back-half side of the frame, and wherein the four rotary wings are positioned
10 inside the frame;

a drive device that drives the four rotary wings;

a control signal generation circuit that generates a control signal for causing the drive device to drive the four rotary wings, wherein the control signal generation circuit is stored in a waterproof case and the waterproof
15 case is positioned between the first pair of rotary wings and the second pair of rotary wings;

and

an imaging camera,

wherein the unmanned aerial vehicle is configured to fly inside a
20 tubular closed-type space extending in a direction other than a vertical direction with driving the four rotary wings while taking images inside the tubular closed-type space by means of the imaging camera,

wherein the four rotary wings, the drive device, the waterproof case, and the imaging camera are integrated using the frame,

25 wherein an upper surface of the frame defines four apertures that correspond respectively with one of the four rotary wings, and each of the four apertures is partly covered by the frame.

[Claim 2]

30 The unmanned aerial vehicle according to claim 1, further

comprising a member for preceding impact which is for causing an impact on a boundary surface in advance when the unmanned aerial vehicle impacts on the boundary surface of the tubular closed-type space.

5 [Claim 3]

The unmanned aerial vehicle according to claim 2, wherein the member for preceding impact is positioned at the side of one edge of the unmanned aerial vehicle and,

when the unmanned aerial vehicle impacts on the boundary surface
10 while flying inside the tubular closed-type space with the side of the one edge as the forward side, the member for preceding impact is configured to impact on the boundary surface on the forward side ahead of the position of the center of gravity of the unmanned aerial vehicle.

15 [Claim 4]

The unmanned aerial vehicle according to any of claims 1 to 3,
wherein the control signal includes an attitude control signal,
and the unmanned aerial vehicle is configured so that the attitude
control signal causes the drive device to drive the rotary wings, and, when
20 the unmanned aerial vehicle is tilted, the attitude of the unmanned aerial vehicle is controlled by reducing the number of rotations of one or some of the rotary wings.

[Claim 5]

25 The unmanned aerial vehicle according to any of claims 1-4,
wherein the drive device includes four motors which provide the respective rotary wings with motive powers, respectively, and
each of the motors are configured to provide the rotary wing with
motive power at a position with a higher gravitational potential than the
30 rotary wing which receives motive power from the each motor.

[Claim 6]

The unmanned aerial vehicle according to any of claims 1 to 5, further comprising a thrust generation propeller inside the frame, and

5 wherein the unmanned aerial vehicle is configured to propel by rotations of the thrust generation propeller while floating by rotations of the four rotary wings.

[Claim 7]

10 The unmanned aerial vehicle according to any of claims 1 to 6, further comprising a direction of travel imaging camera and a direction of travel imaging data transmitter,

 wherein the unmanned aerial vehicle is configured to fly inside the tubular closed-type space while taking images of the direction of travel
15 inside the tubular closed-type space by means of the direction of travel imaging camera and while transmitting, to the outside, the obtained direction of travel imaging data from the direction of travel imaging data transmitter.

20 [Claim 8]

The unmanned aerial vehicle according to any of claims 1 to 7, wherein the tubular closed-type space is a tubular space in a sewerage pipeline.

25 [Claim 9]

A method of causing an unmanned aerial vehicle having:

a frame having a shape elongated along the forward direction;

 four rotary wings consisting of a first pair of rotary wings and a second pair of rotary wings, wherein the first pair of rotary wings is a pair of
30 two rotary wings positioned on the front-half side of the frame and the

second pair of rotary wings is a pair of two rotary wings positioned on the back-half side of the frame, and wherein the four rotary wings are positioned inside the frame;

a drive device that drives the four rotary wings;

5 a control signal generation circuit that generates a control signal for causing the drive device to drive the four rotary wings, wherein the control signal generation circuit is stored in a waterproof case and the waterproof case is positioned between the first pair of rotary wings and the second pair of rotary wings;

10 and

an imaging camera, wherein the four rotary wings, the drive device, the waterproof case, and the imaging camera are integrated using the frame,

wherein an upper surface of the frame defines four apertures that correspond respectively with one of the four rotary wings, and each of the
15 four apertures is partly covered by the frame;

to fly inside a tubular closed-type space extending in a direction other than a vertical direction with driving the four rotary wings while taking images inside the tubular closed-type space by means of the imaging camera.