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(54) **Title:** IN-PIPE PANORAMIC INSPECTION SYSTEM

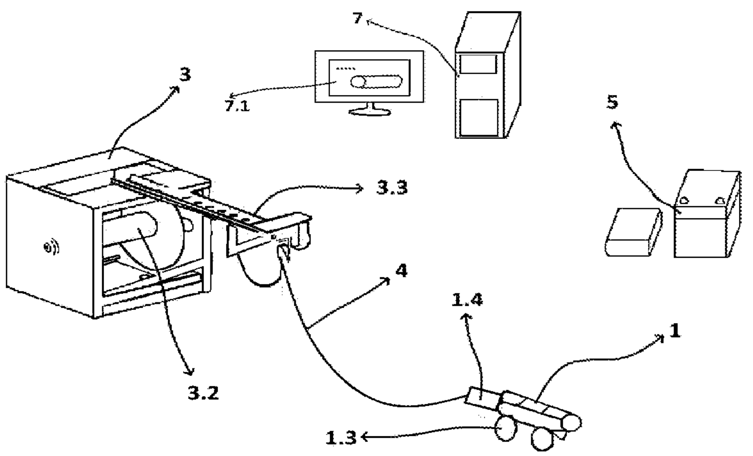

Figure -5

(57) **Abstract:** In particular, the invention relates to an in-pipe panoramic inspection system that can perform panoramic imaging and reporting, providing monitoring and inspection of urban infrastructure systems and transferring images with high resolution.

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IN-PIPE PANORAMIC INSPECTION SYSTEM

Technical Field

The invention generally relates to a robotic in-pipe panoramic inspection system to be used in urban infrastructure systems.

In particular, the invention relates to an in-pipe panoramic inspection system that can perform panoramic imaging and reporting, providing monitoring and inspection of urban infrastructure systems and transferring images with high resolution.

State of the Art

Today, in-pipe monitoring, or in other words, channel monitoring systems is becoming increasingly common in both quality control and fault detection. The most important reasons behind this prevalence are the advancement of technology in robotics, camera and control software, the increase in access to technology and the fact that it becomes affordable. These systems are used by infrastructure contractors providing urban infrastructure cleaning, maintenance and repair services. They are primarily used by pipe manufacturers/contractors and other private organizations for troubleshooting purposes and by public institutions such as municipalities, provincial banks, urban housing authorities and others. It is also used to monitor infrastructure systems during the quality control stages before the delivery of work. Another common usage area is for quality control purposes after infrastructure cleaning.

Within the vertical, T-joint, horizontal, reduction (diameter changer), Y-joint and elbow joint pipe types seen in Figure 1, PIG, caterpillar, worm, propeller, legged, wall-press and wheeled inspection robots can walk, respectively, as seen in Figure 2. In-pipe robots are categorised according to their mode of movement. For each of these different types, the mechanism, navigation, advantage, disadvantage, and control techniques vary.

For example, for PIG (Pipeline Inspection Gauge) type robots, inspection can be performed while the flow continues without having to stop the flow of liquid or gas in the pipe, because these types of robots move on their own with the liquid or gas pressure in the pipe and do not need a propulsion system (e.g., motor). They can therefore serve long distances (up to 200 km) and take less time to complete the operation. However, it is difficult to transport to variable pipeline diameter. The pipe diameter should not change during the voyage and sharp turns are not possible.

In Worm (Inchworm) type inspection robots, the grip strength is higher than other types. For this reason, they can move in inclined, horizontal, vertical, and variable diameter pipes and generate less traction (torque) compared to other types.

Screw type inspection robots reduce damage to the inner wall of the pipeline during movement. However, they can work without stopping the flow of liquid or gas. They can also move in inclined, horizontal, vertical and variable diameter pipes. However, once served to the pipeline, they cannot be withdrawn and steering them is difficult and complex. Difficulty in steering also brings deviations at intersections.

Walking/Legged type inspection robots cause only minor damage to the walls of the pipe. Skidding is minimal and they can easily climb even vertical pipes. They can move in inclined, horizontal, vertical, and variable diameter pipes. The disadvantages are the complex mechanism, jamming inside the pipe when the mechanism fails, and low mobility.

Wall-Press type inspection robots are lighter and smaller in structure. High friction can be created in the line of motion between this type of robot and the inner surface of the pipe. They have a wide range of communication. They can move in inclined, horizontal, vertical, and variable diameter pipes, but high friction damages the inner wall of the pipe. Since steering them is difficult and complex, they progress more slowly than other types.

Wheel type inspection robots, the type in which our invention was also carried out, have a simple mechanism. They create less friction between the robot and the pipe inner wall. They have high mobility. They can move in inclined, horizontal, and variable diameter pipes, but the little friction between the robot and the pipe inner wall increases the chances of skidding. Wheel type pipeline inspection robot is a normal mobile robot that works on a basic mechanism by turning wheels using various actuators (drive) for driving power. Various inspection sensors are mounted on these robots and sent to pipelines for inspection.

Inspection is performed by placing optical sensors on the wheeled inspection robot. At least two camera sensors are needed for panoramic imaging. Between these two camera sensors are the body and drive system. Therefore, there is a distance between the two cameras. In urban infrastructure systems, pipes start from a minimum diameter of 150 millimetres. The relatively small pipe diameters and the distance between the two cameras are challenging for panoramic image creation.

Another problem faced by wheeled robotic systems is the problem of skidding. Skidding affects the dynamics as well as the accuracy of the position information and deviates it. In wheeled robotic systems, the main condition that forces the accuracy of the system and the information it collects is the skid condition. Skidding both creates operational problems and causes deviations in position information. Deviations in position information also cause images to overlap in panoramic image creation.

In the invention numbered TR 2020/20310 in the prior art, a laser waste water channel monitoring robot is explained. The invention relates to a laser imaging robot, which enables the detection of narrowing and blockages in the inner part of the waste water lines by visualizing and learning the cause of the malfunction in the malfunctioning pipe systems and provides convenience in subsequent studies by means of the image and report taken at the end of the work. The invention provides a circular measurement in the channel and adds the deformation in the channel to the reports. It enables the measurement of crack sizes, crack intervals and the length of materials such as stone, concrete, and iron board that will prevent water flow. For these purposes, the invention comprises elements such as body, gear group, cover, motor, wheel, socket, lift motor, lift arm, lift body, LED, laser, temperature sensor, camera, lock system, pressure sensor, probe, head collection system, adjustment system, automatic balance system, head motor and etc. However, in mentioned invention, it is not mentioned that the image taken is panoramic (360 degrees) and that it is obtained by the method in our invention.

In the document with the publication number CN102608124A, another document in the current art, the micro pipe internal defect and appearance measuring device and method are explained. The invention provides a micro in-pipe defect and appearance measuring device with flexibility, automation, speed, online and similar performance characteristics to meet the measurement requirements of the small-sized modern industry and a method. To achieve the objectives, the invention comprises a micro in-pipe defect measuring and appearance measuring sensor, wherein the sensor consists of an optical transmission part, a lighting source, and a camera; the sensor is fixedly connected with a tail end joint of an industrial robot; the data of the in-pipe 360-degree cylindrical surface annular panoramic picture shot by the camera is transmitted by the optical transmission part and is collected by an image acquisition card to be processed by a computer. Micro in-pipe defect measuring and appearance measuring device and the method are mainly applicable to micro in-pipe defect measurement. However, despite the mention of taking a panoramic image in mentioned invention, there is no working with the method in our invention. In addition, features such as automatic positioning were not encountered.

Another similar application that provides wheeled and panoramic imaging in the state of the art can be found in https://www.ibak.de/en/produkte/ibak_show/frontenddetail/product/panoramo-4k/. In terms of service distance, our invention can provide service at a distance 60 meters further (360 meters to 300 meters) than the product in the relevant link. It weighs much less. It comprises temperature and tilt sensors. While there are two independent motors in our invention, there is a single motor in the product in mentioned link.

The operation of the product in the link above is explained in https://www.youtube.com/watch?v=LWqW5Ra_fOo. Every 5 centimetres, the Zeon headlights turn on and the image is recorded. However, there is a problem that needs to be defined here. We can call this problem the "Blind Field Problem". The blind area problem is caused by the distance between the two cameras. When you place a fisheye lens camera on the front and back of the robot seen in Figure 3, the lights/images/textures instantly collected by the two cameras are not a complete 360-degree (panoramic) image in real time, due to the distance between them. The cameras capture different points at the same time because of the distance between them. Again, if we explain through figure 3, when the 185-degree fisheye camera lenses used in the robot in the link are placed on the front and back of the robot, the interval between the notes where 185 degrees ends is between the dashed lines shown in figure 3 and both cameras shoot different points of the pipe at this time and are unable to create a precise 360 degree panoramic view (around a single point). This results in the fact that the dashed lines cannot be displayed in real time.

The panoramic image acquisition technique used by the products in the links is to match the frames (frame) received from the camera sensors with the position information received from the distance meters of the robot, and to match the frames received when the rear camera comes to the position of the front camera at any particular time. In other words, as seen in Figure 4, an image is taken from the front camera while the robot is moving, since the dimensions (distance), position and speed of the robot are known, it can be calculated when the rear camera will reach the point where the front camera takes the image, and after that time, images are taken from the rear camera, and these are matched. The robots in the links aim to solve the blind area problem in this way. However, there are disadvantages of obtaining panoramic images in this way.

The wheel diameter reducing with the wear of the wheel systems over time, the camera sensors not coinciding with the middle of the pipe, causing deviations in the position information, deviations in the position information between the front camera and the rear camera, and the processing of images that are different from the real/physical image, and gradual increase in this margin of error are some of the disadvantages.

Another problem is the flashing of the Zeon lighting. (not carrying on continuously) This lighting blink every 5 cm, ensuring that the panoramic view of the received frames is properly lighted, but it is not ideal for the use of the operator. The user experience is that the non-stop flashing makes it difficult to use.

Another disadvantage of the robot in the link is that it is heavier and larger than our model. This prolongs the operational times and makes it difficult for the robot to service the channel. At the same time, using a single engine for the propulsion system creates the danger of being forced at lateral angles and tipping over in bent channels.

In order to determine the state of the art, the documents with the publication numbers TR 2020/04694, TR 2019/15386, TR 2011/05212, TR 2007/06370, CN 110319299A, CN 209417316U and US 2018089896A1 can also be reviewed, however, neither in the documents mentioned above nor in other descriptions in the state of the art, a system and method with exactly the same features as our invention is mentioned.

Conclusively, due to the above-described problems and the insufficiency of the existing solutions made it necessary to make an improvement in the relevant technical field.

The Aim of the Invention

The invention was created to solve the abovementioned negativities by being inspired by the current situation.

The main aim of the invention is to provide a robotic in-pipe panoramic inspection system to be used in urban infrastructure systems.

Another aim of the invention is to provide an in-pipe panoramic inspection system that can perform panoramic imaging and reporting, providing monitoring and inspection of urban infrastructure systems and transferring images with high resolution.

Another aim of the invention is to provide an in-pipe panoramic inspection system with less friction between the robot and the inner pipe wall, high mobility, and a reduced possibility of skidding between the robot and the inner pipe wall.

Another aim of the invention is to provide an in-pipe panoramic inspection system with increased accuracy of position information by reducing the possibility of skidding between the robot and the inner pipe wall.

Another aim of the invention is to provide an in-pipe panoramic inspection system that solves the problem of obtaining panoramic images caused by the distance between the front and rear cameras.

Another aim of the invention is to provide an in-pipe panoramic inspection system, which reduces operational times as it is lighter, faster and smaller than its counterparts.

Another aim of the invention is to provide an in-pipe panoramic inspection system that can move faster than its counterparts in right-to-left turns in the pipe as it has a double drive motor.

In order to fulfil the purposes described above, the invention is an in-pipe panoramic inspection system that provides monitoring, inspection, and panoramic image transfer of urban infrastructure systems, comprising

- at least one robot moving back and forth within the infrastructure system,
- at least one front camera with a fisheye lens, which is located at the end of mentioned robot in the direction of its progress, and enables the image to be taken from the inner section of the infrastructure system,
- at least one rear camera with a fisheye lens, which is located at the opposite end of the direction in which mentioned robot is advancing, and enables the image to be taken from the inner section of the infrastructure system,
- at least one wheel, located on the sides of mentioned robot, and enables the robot to move to back and forth within the infrastructure system,
- at least one body, which is the carrier surface that enables mentioned front camera, rear camera and wheel to be positioned on the robot,
- at least one drum system that enables mentioned robot to be released and withdrawn into the infrastructure system,
- at least one cable between mentioned robot and the drum system, which provides the transfer of images taken from the front and the rear cameras, the transmission of the energy required for the robot to move, the tracking of the robot's position information, and the communication between the robot and the drum system,
- at least one power system that provides the energy needs of the inspection system,
- software that enables panoramic images to be obtained from the images taken from the aforementioned front and rear cameras,

- at least one lidar system that reads the distance to the inner section of the infrastructure system pipe and enables mentioned robot to move by positioning it at the midpoint of the pipe,
- at least one first motor that drives the wheels on the right side of mentioned robot,
- at least one second motor operating independently of mentioned first motor, which prevents skidding by moving the wheels on the left side of the robot,
- at least one lighting system that illuminates the interior of the infrastructure system and ensures that the images taken from mentioned front camera and/or rear camera are clear,
- at least one robot control system that enables the movements of mentioned robot to be controlled, and
- at least one robot encoder that ensures obtaining the position information of mentioned robot in the pipe.

The structural and characteristic properties and all advantages of the invention will be more clearly understood with the figures given below and the detailed description written with reference to these figures and therefore, the assessment should also be made by taking these figures and the detailed description into account.

Figures to Help Understand the Invention

Figure 1. is the representative view of the pipe types.

Figure 2. is the representative view of the inspection robot types.

Figure 3. is the representative view of defining the blind area problem on the inspection robot.

Figure 4. is the representative view of one of the solutions of the blind area problem on the inspection robot.

Figure 5. is the representative view of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 6. is the representative perspective view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 7. is the representative front view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 8. is the representative rear view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 9. is the representative side view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 10. is another representative side view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 11. is the representative top view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 12. is the representative exploded view of the robot and the lift system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 13. is the representative exploded view of the front camera of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 14. is the representative exploded view of the rear camera of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 15. is the representative exploded view of the wheel configuration of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 16. is the representative exploded view of the socket structure of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 17. is the representative exploded view of the body structure of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 18. is the representative exploded view of the robot of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 19. is the representative exploded view of the lift of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 20. is the representative view of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 21. is the representative exploded view of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 22. is the representative exploded view of the worm shaft of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 23. is the representative exploded view of the winding core of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 24. is the representative exploded view of the boom extension of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 25. is the representative exploded view of the transmission system of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Figure 26. is another representative exploded view of the transmission system of the drum system of the in-pipe panoramic inspection system, which is the subject of the invention.

Description of Part References

1. Robot

1.1 Front Camera

1.2 Rear Camera

1.3 Wheel

1.4 Socket

1.5 Body

2. Lift

3. Drum System

3.1 Worm Shaft

3.2 Winding Core

3.3 Boom Extension

3.4 Transmission System

4. Cable

5. Power System

6. Software

7. Computer

7.1 Interface

Detailed Description of the Invention

In this detailed description, the in-pipe panoramic inspection system that is subject of the invention and its preferred embodiments are explained only for a better understanding of the subject, without any restrictive effect.

Figure 5 is the representative view of the in-pipe panoramic inspection system that provides monitoring, inspection and panoramic image transfer of urban infrastructure systems.

The in-pipe panoramic inspection system comprises a robot (1) that moves back and forth within the infrastructure system.

In a preferred embodiment of the invention, there is a temperature sensor that enables the temperature of the robot (1) inside the infrastructure system to be measured.

In a preferred embodiment of the invention, mentioned robot (1) comprises a tilt sensor that enables the inclination of the pipe in the infrastructure system to be measured.

In-pipe panoramic inspection system also comprises a front camera with a fisheye lens (1.1), which is located at the end of mentioned robot (1) in the direction it is advancing and enables the image to be taken from the inner section of the infrastructure system (1.1) and a rear camera (1.2) with a fisheye lens, which is located at the opposite end of the direction in which mentioned robot (1) is advancing and enables the image to be taken from the inner section of the infrastructure system.

In a preferred embodiment of the invention mentioned robot (1) comprises the lift (2) that prevents mentioned robot (1), the front camera (1.1) and/or the rear camera (1.2) from hitting the inner section of the pipe by moving up and down in the pipe, and the lift motor that enables mentioned lift (2) to move.

Mentioned lift (2) is preferably scissor type.

In a preferred embodiment of the invention, there is a computer (7) that provides processing of images taken from mentioned front camera (1.1) and rear camera (1.2) and an interface (7.1) that enables the images taken from mentioned front camera (1.1) and the rear camera (1.2) to be displayed and reported on mentioned computer (7).

In the in-pipe panoramic inspection system, there is a wheel (1.3) located on the sides of mentioned robot (1), which enables the robot (1) to move back and forth within the infrastructure system and a body (1.5), which is the carrier surface that enables mentioned front camera (1.1), rear camera (1.2) and wheel (1.3) to be positioned on the robot.

In a preferred embodiment of the invention, mentioned robot (1) may comprise a valve that allows nitrogen gas to be filled and/or discharged to the body (1.5) for the movement of mentioned robot (1), a pressure sensor that enables the pressure in mentioned body (1.5) to be measured and monitored and a sealing element that ensures the sealing of the nitrogen gas in mentioned body (1.5).

The in-pipe panoramic inspection system comprises the drum system (3) that allows mentioned robot (1) to be released and withdrawn into the infrastructure system.

In a preferred embodiment of the invention, mentioned drum system (3) comprises a drum motor that provides rotation, a worm shaft (3.1), which is connected to mentioned drum motor and enables the cable (4) to be released or wound by rotating, a winding core (3.2), which is the surface on which the cable is released or wound and is connected to mentioned worm shaft (3.1), a boom extension (3.3), which facilitates the robot (1) to move forward and/or backward in the pipe by stretching the cable (4) extending from mentioned winding core (3.2) into the pipe by means of its spring mechanism and rope potentiometer, a transmission system (3.4), which enables the adjustment of the transmission ratio between mentioned drum motor and the winding core (3.2), a drum drive, which enables the speed of mentioned drum motor to be controlled by adjusting, a drum brake which provides slowing and/or stopping of mentioned drum motor, and drum encoder, which enables measuring the quantity information of the released cable.

In a preferred embodiment of the invention, the communication protocol between mentioned robot (1) and the drum system (3) is RS485.

In the in-pipe panoramic inspection system, there also is the cable (4) located between mentioned robot (1) and drum system (3), enabling the transfer of images taken from the front camera (1.1) and the rear camera (1.2), the transmission of the energy required for the robot to move, the tracking of the position information of the robot (1) and the communication between the robot (1) and the drum system (3).

In a preferred embodiment of the invention, there is a socket (1.4) that provides electrical and physical connection between the robot (1) and the cable (4).

In the in-pipe panoramic inspection system, There also is a power system (5) that provides the energy requirement of the inspection system.

In a preferred embodiment of the invention, mentioned power system (5) comprises the battery from which the power to be transferred to the robot (1) is received, the regulated power supply that enables the power to be transferred from mentioned battery to the robot (1) and the inverter that enables mentioned computer (7) to be operated by adjusting the power taken from mentioned battery.

In the in-pipe panoramic inspection system, there is a software (6) that enables panoramic images to be obtained from the images taken from mentioned front camera (1.1) and rear camera (1.2).

In a preferred embodiment of the invention, there is a software (6) that enables taking images from mentioned front camera (1.1), matching the position where the image from mentioned front camera (1.1) is taken with the image taken, taking images from mentioned rear camera (1.2), subtracting the distance between mentioned front camera (1.1) and rear camera (1.2) from the paired position, obtaining the reference value of the position information of the image taken from the rear camera (1.2) by subtraction, adding +/- margin of error to the obtained reference value, obtaining the image set to search for a match by adding the margin of error, bringing the images taken from mentioned front camera (1.1) and rear camera (1.2) into a rectangular form, reversing the image taken from mentioned rear camera (1.2), bisecting the image of the reversed rear camera (1.2), searching for texture matches between the reversed and bisected rear camera (1.2) images and the front camera (1.1) image in the resulting image set and if a match is found, stitching the matching images together to obtain a panoramic image.

In the in-pipe panoramic inspection system, lidar system, which reads the distance to the inner section of the infrastructure system pipe and allows mentioned robot (1) to move by positioning it at the middle of the pipe comprises the first motor that enables the wheels (1.3) on the right side of mentioned robot (1) to be moved, and the second motor that works independently of mentioned first motor and ensures the prevention of skidding by moving the wheels (1.3) on the left side of the robot (1).

In a preferred embodiment of the invention, the robot (1) may have a gear and shaft system that provides the transfer of motion by adjusting the speed between the first engine, the second engine and the wheels (1.3).

Finally, in the basic structuring of the in-pipe panoramic inspection system, there are the lighting system that illuminates the interior of the infrastructure system and ensures that the images taken from mentioned front camera (1.1) and/or rear camera (1.2) are clear, the robot control system to control the movements of mentioned robot (1) and the robot encoder that provides the position information of mentioned robot (1) in the pipe. The lighting system is preferably LED.

In-pipe panoramic inspection system realizes panoramic imaging and reporting method with two-axis dynamic drive-in construction and infrastructure industry, environmental technologies and in-pipe engineering, in wheeled robotic applications.

Unlike conventional sewer inspection systems, our invention uses two high resolution cameras (1.1, 1.2) with 185° fisheye lenses. The use of fisheye technology makes it possible to shoot videos with extremely wide-angle focal lengths. With the image files created in this way, the perspective from which you want to see an object, or a defect can be freely chosen and also enables a virtual sewer inspection in the office. Therefore, the person performing the analysis of defects need not be the same as the operator. It becomes possible for one to stop the robot (1), intentionally pointing to a defect, and unlike the inspection with conventional technology, where one has to document it, our invention can be scanned without any stops. The condition of the pipe can be evaluated in the office at a different time than the scan. This makes it easy to plan time lines for sewer inspections by scanning the cameras (1.1, 1.2) without having to stop and aim, it always takes roughly the same amount of time, regardless of the number of objects in the pipe.

Real-time distance measurement is made with the lidar system on the front camera (1.1) head – preferably 3 pieces – so that the robot (1) is always located in the middle of the pipe, and this process is carried out automatically. At the same time, when a manoeuvre is made that will cause the robot (1) to topple without the initiative of the operator, the distance information obtained from the lidar system is instantly correlated, and the right or left command is given automatically, and the possibility of tipping is eliminated. At the same time, in case of a narrowing in the pipe, the lift (2) takes action in real time and provides protection against unwanted impacts.

While obtaining a panoramic image, it is aimed to eliminate the errors that will occur due to the deviations in the position information. At the same time, the blind area problem is solved by these methods. The 185-degree fisheye image obtained from the front and rear cameras (1.1, 1.2) is made rectangular. (Equirectangular projection) The frame (image frame) taken from the rear camera (1.2) is bisected into two equal parts and placed on the right and left of the image taken from the front camera (1.1), texture matching is done. (Pattern recognition) Frames with matched textures are stitched and a panoramic image is obtained. (Stitching) Position information is used to minimize the matching times of the front and rear frames. When the rear camera (1.2) comes to the position of the front camera (1.1) at any time and position, frames covering a certain distance in front and back (+/- position) are clustered. And this set is searched for texture matching. It saves time and the number of frames that need to be scanned. The system is optimized. Panoramic image processing is matched with frame information from the front camera (1.1) at any position. The distance between the two camera sensors (1.1, 1.2) is subtracted from the matched position information and the reference value for the position information of the frame in the rear camera (1.2) sensor is obtained. The margin of error value (±) is added to this reference value and the frame set is obtained. With the front frame, the frames in the rear frame set are rendered without distortion and have a rectangular form. The rear sets of frames are rotated (inverted) and bisected. Texture matching is done in the 2.5° common area between the front frame and the rear frame set. Matching frames are stitched together, and a panoramic image is obtained. In this way, a panoramic image is obtained without any margin of error (deviations in position). In the state of the art, this mechanical tissue matching is a new method in obtaining panoramic images.

Our software includes both GUI (graphical user interface) interface (7.1) and panoramic image acquisition and reporting. Embedded system software (6) is also included in the system.

The features of our invention are also summarized below;

Pipe Diameter Working Range	Between 200 mm (millimetre) and 1400 mm
Service Distance	360 metres
Approximate Weight	21 kg (kilogram) (smallest wheel diameter, no lift)
Sealing	IP 68
Sensors	Pressure, Temperature, Tilt
Reporting Standard	WRc, BS EN 13508-2
Operating Temperature	0°C– + 40°C during operation -30°C– + 70°C for storage
Walking System	Double Independent Engine, preferably 4 Wheels
Compressive Strength	1 bar
Robot Walking Speed	400 mm/s
Robot Climbing Slope	± 60°
Camera Features	185° (optional) Fisheye Lens
Camera Lighting	Camera External Surface min700 Lumen LED Adjustable
Camera Resolution	1920 X 1080 (1K), Optional 4K (4096 X 2160)
Panoramic View	Yes

Panoramic Format	Video (1 fps)
Camera Head	Fixed
Autonomous Reporting Eligibility	Yes
Laser Hardware	No

Table 1. Features of the in-pipe panoramic inspection system that is the subject of the invention

In the pipe inspection system within the scope of the invention, there are panoramic view cameras (1.1, 1.2) and the robot (1) that makes the cameras (1.1, 1.2) advance and rise and fall in the channel and the drum system (3), which releases and/or collects the cables (4) to be used for image/signal/energy transmission in an ideal tension.

The cameras (1.1, 1.2) in the channel surveillance robot (1), which is the subject of the invention, are aluminium, cylindrical and have IP 68 protection (absolutely dustproof, protected against the effects of continuous immersion in water). Robot (1) performs the visualization of channels with diameters between 200-1400 mm. As a requirement of the process of processing the images obtained during panoramic imaging, the image must be taken from the cross-sectional centre of the channel. For this reason, the cameras (1.1, 1.2) are arranged on a height adjustment mechanism that can be raised or lowered to coincide with the centre of the channels of different diameters. This mechanism can be easily disassembled and mounted. The lift (2) is driven by an lift motor, which is a single (linear) actuator. Although the robot (1) is kept small in size, its right and left wheels (1.3) are driven separately in order to have high manoeuvrability and acts like a tracked vehicle. Two separate motors (first motor, second motor) are used, one for driving the left wheels (1.3) and one for driving the right wheels (1.3). The drive taken from these motors is transferred to the wheels (1.3) with a gear and shaft system. The wheel (1.3) connections are easy to disassemble (remove-plug). It is possible to use wheels (1.3) of different sizes and types. For example, a 125 mm wheel (1.3) diameter solution is provided for 200 mm pipe diameter, and a 137 mm wheel (1.3) diameter solution is provided for 300-400-500-600-700-800 mm pipe diameters. In other words, the lift (2) can be removed, and small wheels (1.3) can be used in small diameter channels (200 mm diameter). In large diameter channels, large wheels (1.3) and lift (2) will be used and in this way the cameras (1.1, 1.2) will be positioned at the desired height. For the control of IP68 protection and tightness in the robot (1) and the camera system (1.1, 1.2), both systems are preferably filled with 1 bar pressure nitrogen gas and this internal pressure value is instantly monitored by the pressure sensors. In the event of a pressure drop, a leak in the system can thus be detected.

In the drum system (3), the cables (4) to be used for image/signal/energy transmission from the camera system (1.1, 1.2) are arranged and the distance control measurement is taken by keeping these cables (4) constantly at the appropriate tension. The drum system (3) receives the quantity information of the cable (4) released from the drum encoder and the instant position and advance amount information from the robot encoder on the robot (1). With a special spring mechanism and the information coming from the rope potentiometer connected to this mechanism, the winding core (3.2) in the drum system (3) winds or releases the cable (4), thus keeping the cable (4) in an ideal tension. Sealing elements and wheels (1.3) to be used in the system have been selected to be resistant to heavy chemical conditions in the infrastructure channels.

In the power system (5), the power requirement of the robot (1) is provided by 12 V batteries. A 24VDC-220VAC inverter is used for the 220VAC required for the computer (7). The control unit works with 48VDC. The robot (1) requires 48V 3.5A power and there is a voltage drop depending on the length of the cable (4) used. The solution is provided with an adjustable power supply.

The cable (4) is specially made for the robot control system and the power, data and video transmission of the robot (1). Video transmission is carried out over a fibre-cable (4). Power and communication are provided by copper cables. Uniform cable (4) is used.

The lighting, the temperature sensor, pressure sensor and tilt sensor are used with circuit board.

Mentioned first motor, second motor and lift motor are DC (direct current) motors and are driven by a specially designed circuit board. The mentioned circuit board has multiple encoders reading and PID features.

The reporting process is available in the graphical user interface (7.1) containing the error codes defined in the TS EN 13508-2: 2003+A1:2011 standard. While the errors in the channel are processed by the moderator, a report output is prepared using these codes.

The robot (1) continuously collects images by moving through pipes in urban infrastructure systems. It provides the communication with the computer (7) and software (6) providing the management, and the cable (4) providing energy, power and communication is served. Panoramic image is obtained and reported with two cameras (1.1, 1.2).

By this way, the in-pipe panoramic inspection system, which enables the monitoring and inspection of urban infrastructure systems and the transfer of panoramic images, is introduced.

CLAIMS

1. In-pipe panoramic inspection system that provides monitoring, inspection, and panoramic image transfer of urban infrastructure systems, **characterized by comprising**

- at least one robot (1) moving back and forth within the infrastructure system,
- at least one front camera (1.1) with a fisheye lens, which is located at the end of mentioned robot (1) in the direction of its progress, and enables the image to be taken from the inner section of the infrastructure system,
- at least one rear camera (1.2) with a fisheye lens, which is located at the opposite end of the direction in which mentioned robot (1) is advancing, and enables the image to be taken from the inner section of the infrastructure system,
- at least one wheel (1.3), located on the sides of mentioned robot (1), and enables the robot (1) to move to back and forth within the infrastructure system,
- at least one body (1.5), which is the carrier surface that enables mentioned front camera (1.1), rear camera (1.2) and wheel (1.3) to be positioned on the robot (1),
- at least one drum system (3) that enables mentioned robot (1) to be released and withdrawn into the infrastructure system,
- at least one cable (4) between mentioned robot (1) and the drum system (3), which provides the transfer of images taken from the front camera (1.1) and the rear camera (1.2), the transmission of the energy required for the robot to move, the tracking of the robot's (1) position information, and the communication between the robot (1) and the drum system (3),
- at least one power (5) system that provides the energy needs of the inspection system,
- software (6) that enables panoramic images to be obtained from the images taken from the aforementioned front camera (1.1) and rear camera (1.2),
- at least one lidar system that reads the distance to the inner section of the infrastructure system pipe and enables mentioned robot (1) to move by positioning it at the midpoint of the pipe,
- at least one first motor that drives the wheels (1.3) on the right side of mentioned robot (1),
- at least one second motor operating independently of mentioned first motor, which prevents skidding by moving the wheels (1.3) on the left side of the robot (1),

- at least one lighting system that illuminates the interior of the infrastructure system and ensures that the images taken from mentioned front camera (1.1) and/or rear camera (1.2) are clear,

- at least one robot control system that enables the movements of mentioned robot (1) to be controlled, and

- at least one robot encoder that ensures obtaining the position information of mentioned robot (1) in the pipe.

2. In-pipe panoramic inspection system according to Claim 1, **characterized by comprising** at least one socket (1.4) that provides electrical and physical connection between mentioned robot (1) and cable (4)

3. In-pipe panoramic inspection system according to Claim 1, **wherein** mentioned robot (1) **characterized by comprises**

- at least one lift (2) that prevents mentioned robot (1), front camera (1.1) and/or rear camera (1.2) from hitting the inner section of the pipe by moving up and down in the pipe, and

- at least one lift motor that enables mentioned lift (2) to move.

4. In-pipe panoramic inspection system according to Claim 1, **wherein** mentioned drum system (1) **characterized by comprises**

- at least one drum motor that provides rotation,

- at least one worm shaft (3.1), which is connected to mentioned drum motor and enables the cable (4) to be released or wound by rotating,

- at least one winding core (3.2), which is the surface on which the cable is released or wound and is connected to mentioned worm shaft (3.1),

- at least one boom extension (3.3), which facilitates the robot (1) to move forward and/or backward in the pipe by stretching the cable (4) extending from mentioned winding core (3.2) into the pipe by means of its spring mechanism and rope potentiometer,

- at least one transmission system (3.4), which enables the adjustment of the transmission ratio between mentioned drum motor and the winding core (3.2),

- a least one drum drive, which enables the speed of mentioned drum motor to be controlled by adjusting,

- at least one drum brake which provides slowing and/or stopping of mentioned drum motor, and

- at least one drum encoder, which enables measuring the quantity information of the released cable.

5. In-pipe panoramic inspection system according to Claim 1, **characterized by comprising**

- at least one computer (7) providing the processing of images taken from mentioned front camera (1.1) and rear camera (1.2), and

- at least one interface (7.1) that enables the images taken from mentioned front camera (1.1) and rear camera (1.2) to be displayed and reported on mentioned computer (7).

6. In-pipe panoramic inspection system according to Claim 1, **wherein** mentioned robot (1) **characterized by comprises**

- at least one valve that allows nitrogen gas to be filled and/or discharged to the body (1.5) for the movement of mentioned robot (1),

- at least one pressure sensor that enables the pressure in mentioned body (1.5) to be measured and monitored, and

- at least one sealing element that ensures the sealing of the nitrogen gas in mentioned body (1.5).

7. In-pipe panoramic inspection system according to Claim 1, **characterized by wherein** mentioned robot (1) comprises at least one gear and shaft system that provides the transmission of motion by adjusting the speed between the first motor, the second motor and the wheels (1.3).

8. In-pipe panoramic inspection system according to Claim 1, **characterized by wherein** mentioned robot (1) comprises at least one temperature sensor that enables the temperature inside the infrastructure system to be measured.

9. In-pipe panoramic inspection system according to Claim 1, **characterized by wherein** mentioned robot (1) comprises at least one tilt sensor that allows measuring the tilt of the pipe inside the infrastructure system.

10. In-pipe panoramic inspection system according to Claim 1 or Claim 5, **wherein** mentioned power system (5) **characterized by comprises**

- at least one battery from which the power to be transferred to the robot (1) is taken,

- at least one regulated power source that enables the power to be transferred from mentioned battery to the robot (1), and

- at least one inverter that enables mentioned computer (7) to be operated by adjusting the power taken from mentioned battery.

11. In-pipe panoramic inspection system according to Claim 1, **characterized by wherein** the communication protocol between mentioned robot (1) and the drum system (3) is RS485.

12. In-pipe panoramic inspection system according to Claim 1, **characterized by comprising** the software (6) that enables

- taking images from mentioned front camera (1.1),
- matching the position where the image from mentioned front camera (1.1) is taken with the image taken,
- taking images from mentioned rear camera (1.2),
- subtracting the distance between mentioned front camera (1.1) and rear camera (1.2) from the paired position,
- obtaining the reference value of the position information of the image taken from the rear camera (1.2) by subtraction,
- adding +/- margin of error to the obtained reference value,
- obtaining the image set to search for a match by adding the margin of error,
- bringing the images taken from mentioned front camera (1.1) and rear camera (1.2) into a rectangular form,
- reversing the image taken from mentioned rear camera (1.2),
- bisecting the image of the reversed rear camera (1.2),
- searching for texture matches between the reversed and bisected rear camera (1.2) images and the front camera (1.1) image in the resulting image set
- and stitching the matching images together to obtain a panoramic image if a match is found.

13. In-pipe panoramic inspection system according to Claim 1, **characterized by comprising** at least one lidar system that automatically gives the right or left command by making instant correlation over the distance information and eliminates the possibility of the robot (1) falling over when a situation occurs that will cause the robot (1) to topple.

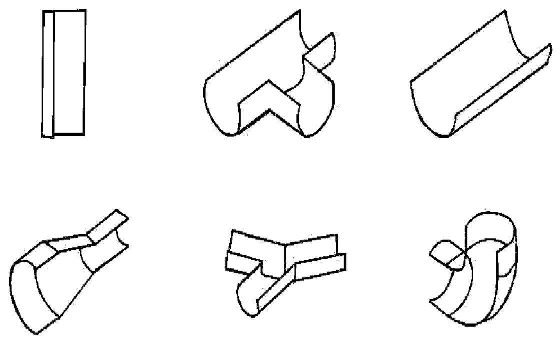


Figure-1

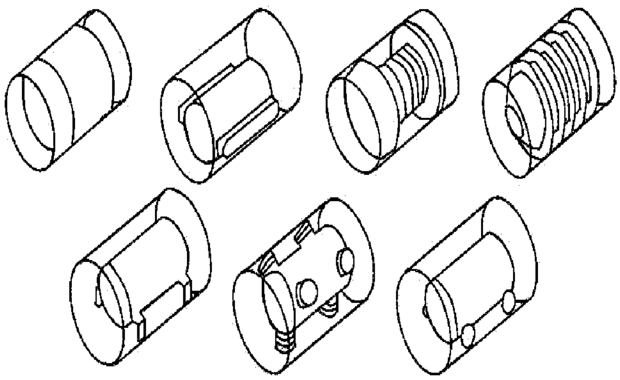
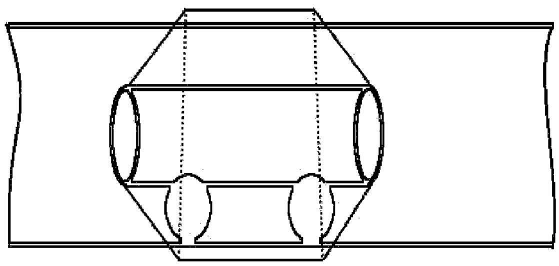


Figure-2



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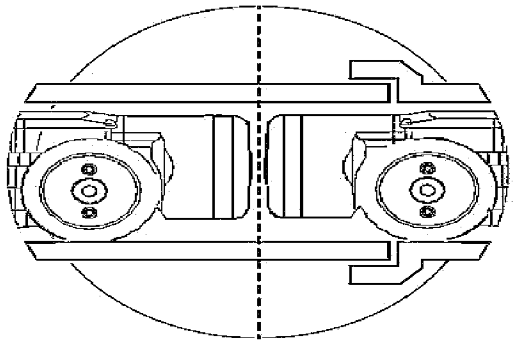

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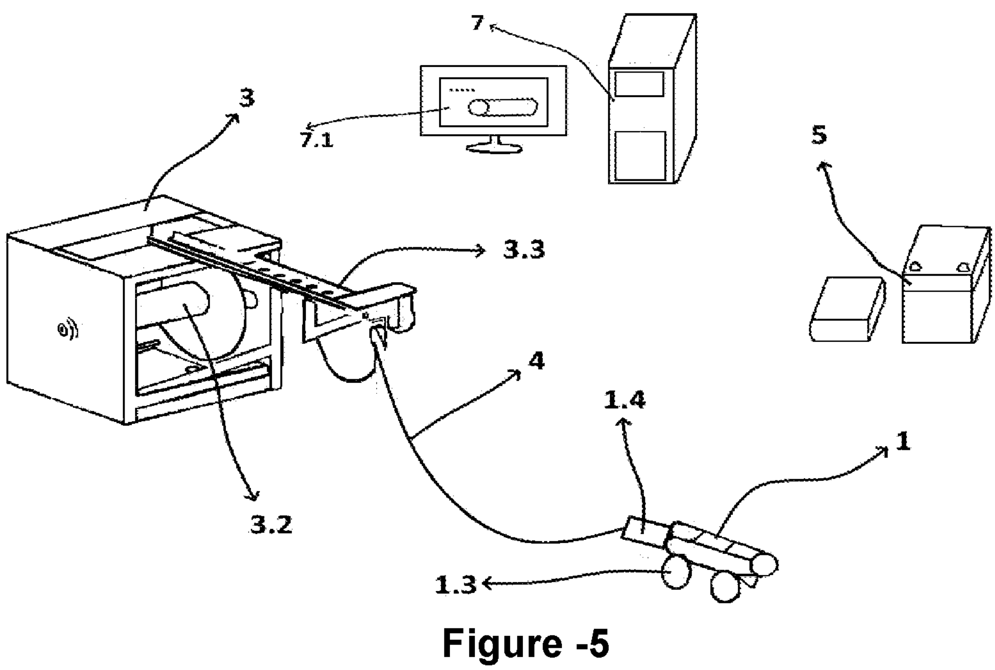

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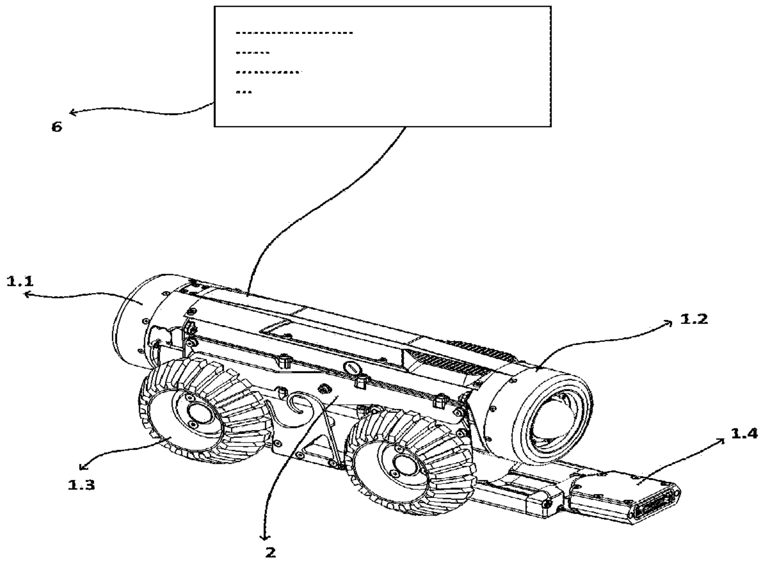

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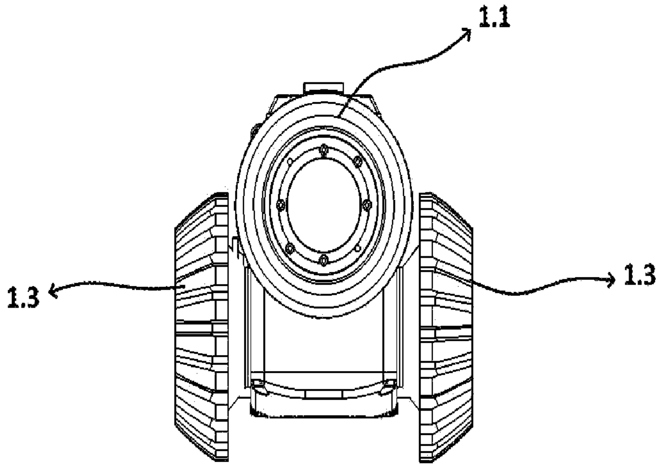

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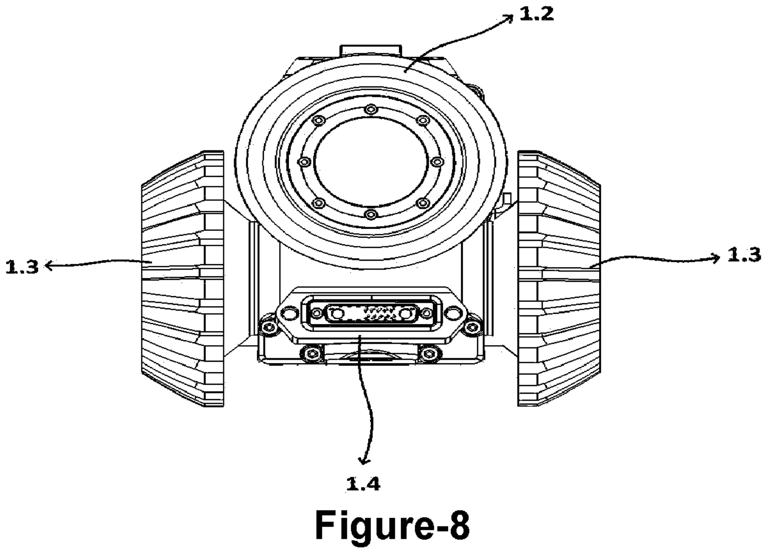

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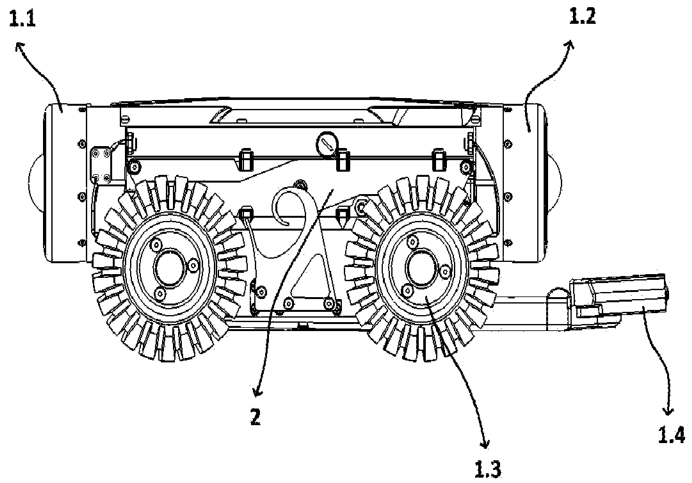

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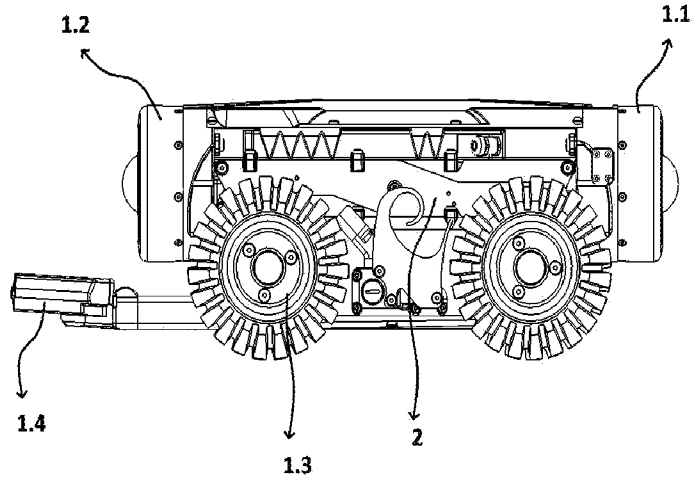

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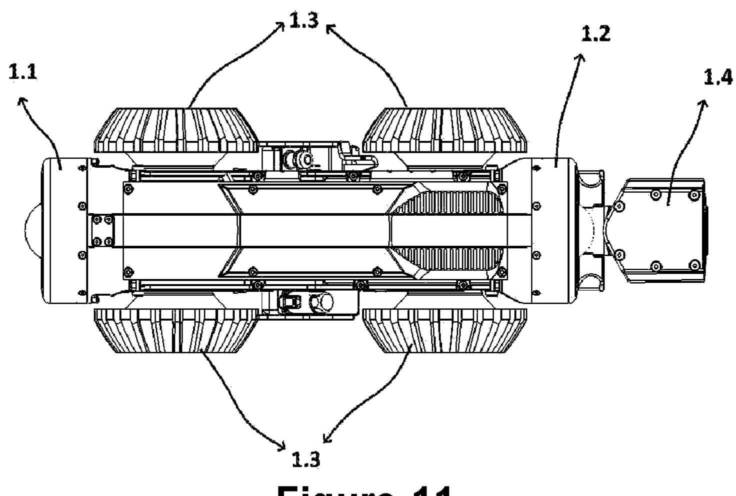

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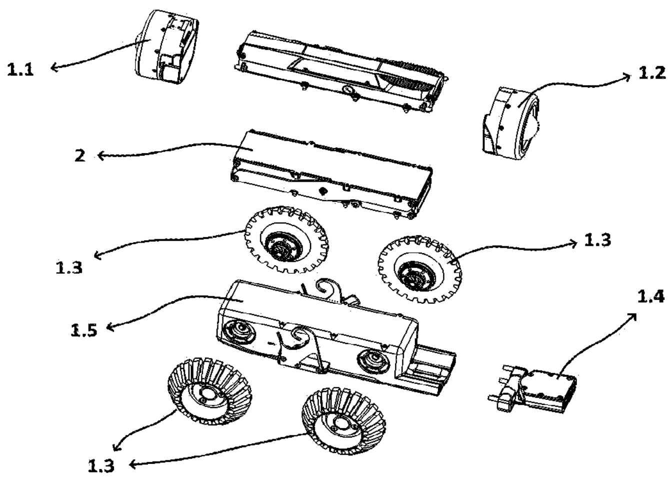


Figure-12

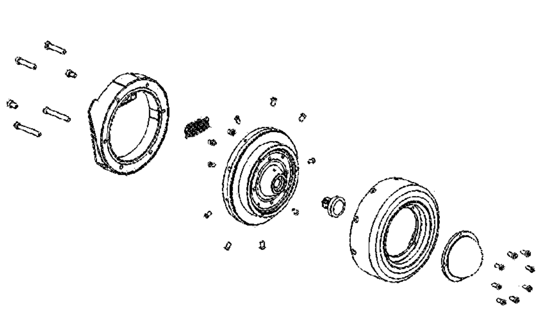
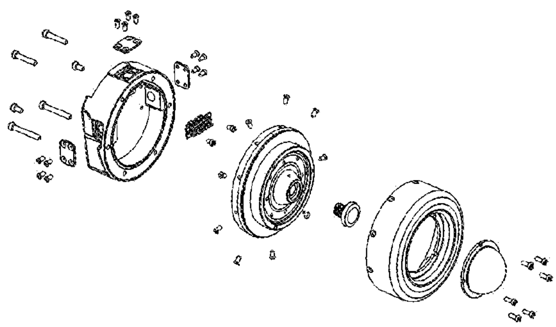


Figure-13



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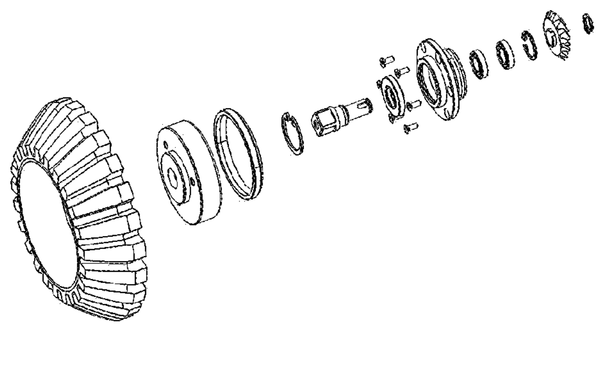


Figure-15

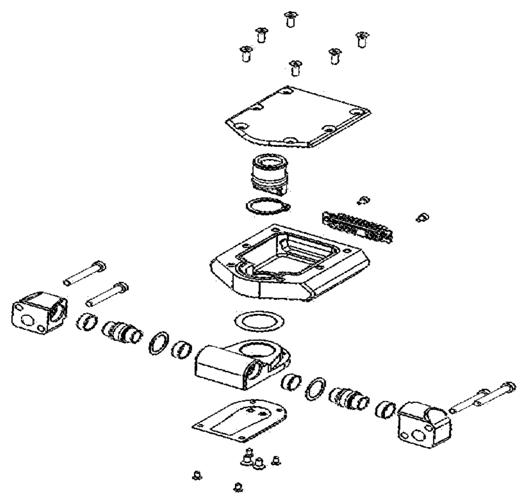


Figure-16

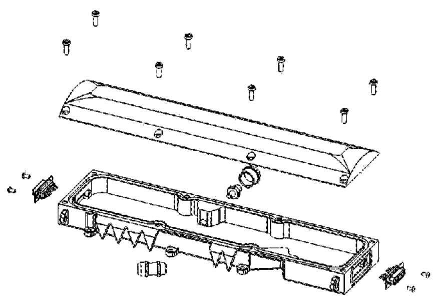
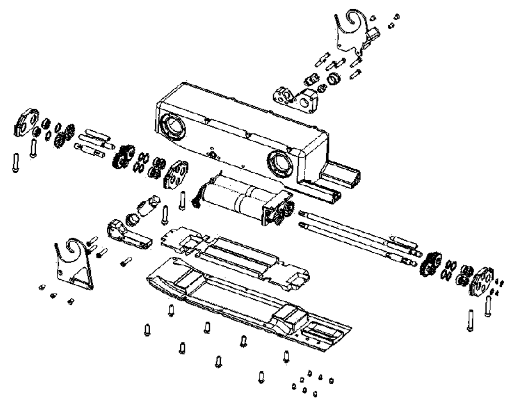


Figure-17



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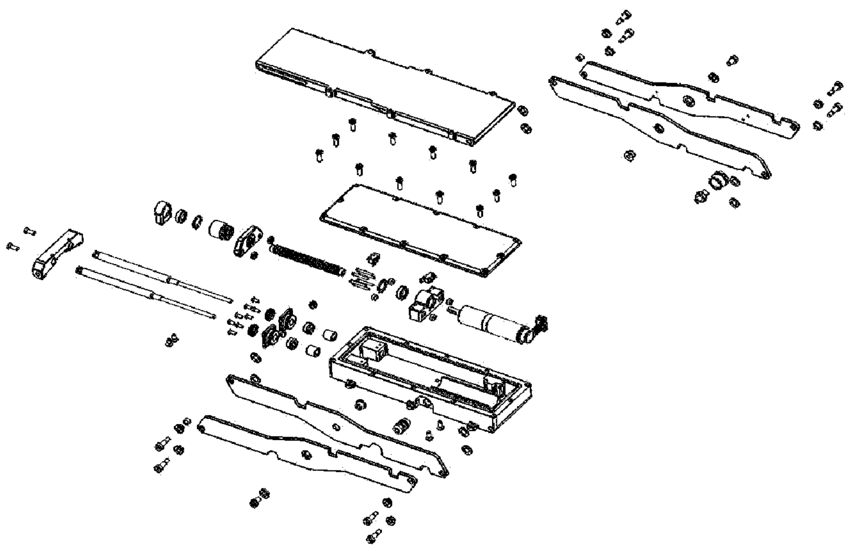


Figure-19

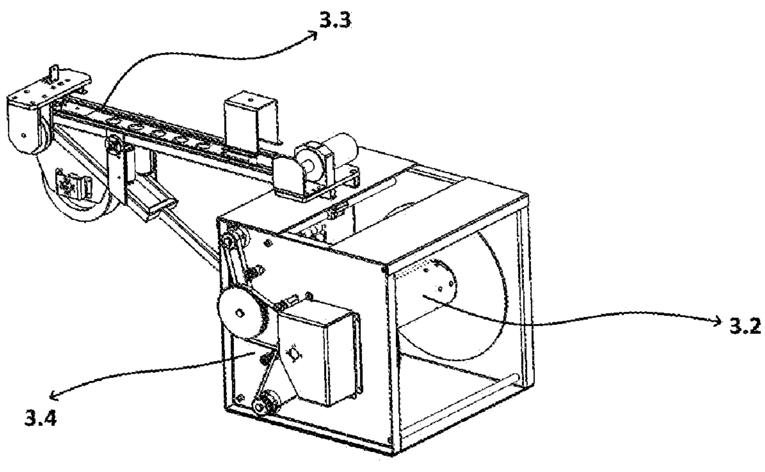
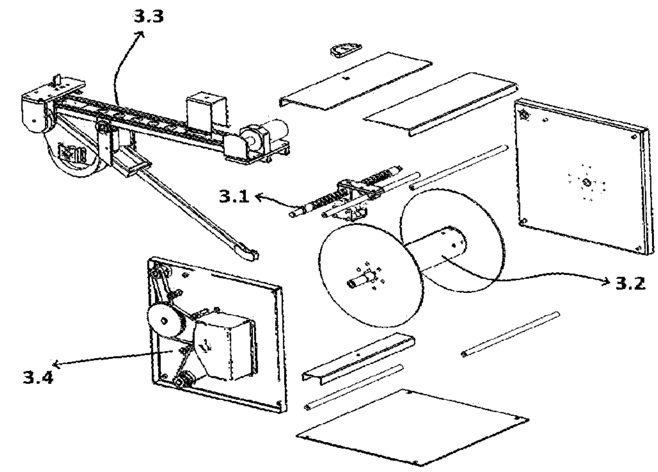


Figure-20



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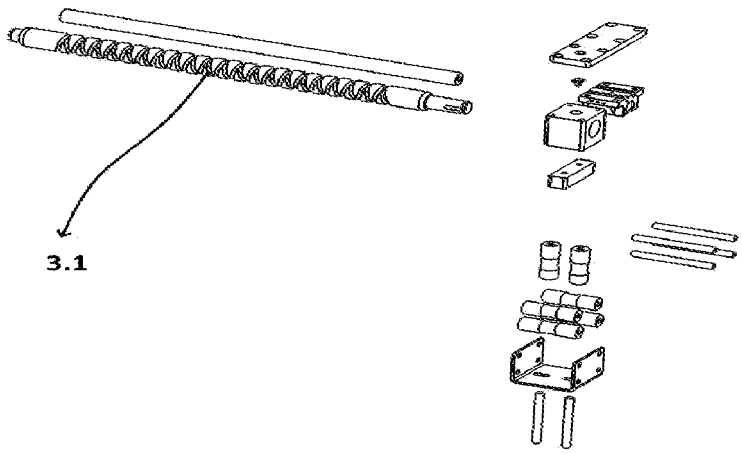


Figure-22

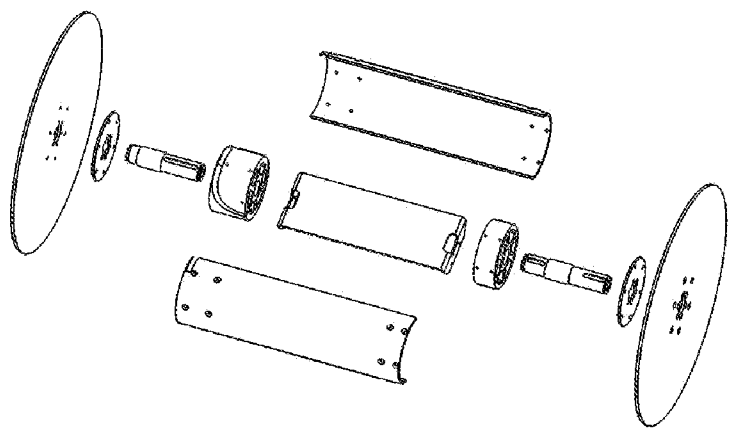
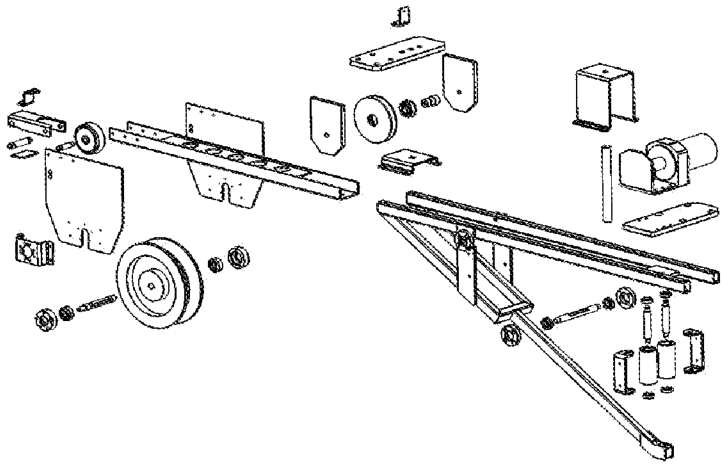


Figure-23



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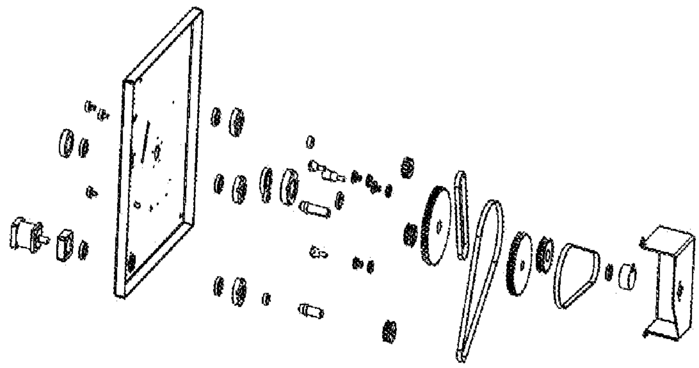

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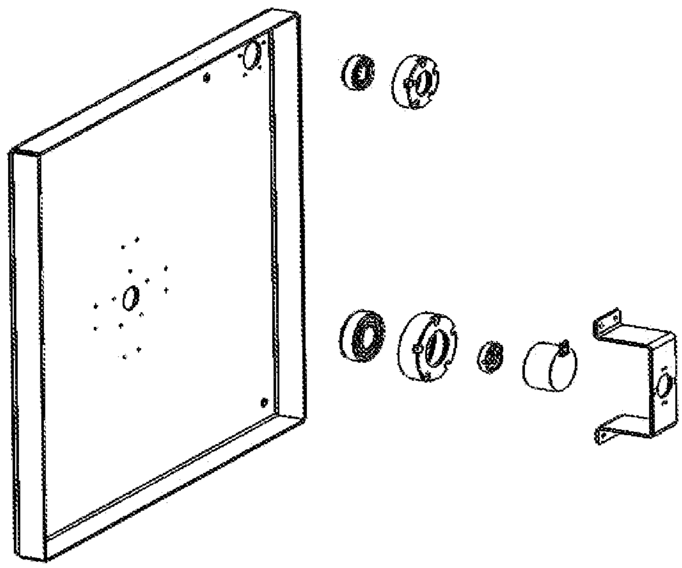

Figure-26