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(54) **Title**: MODULAR TUNNELING AND BORING ROBOTIC SYSTEMS

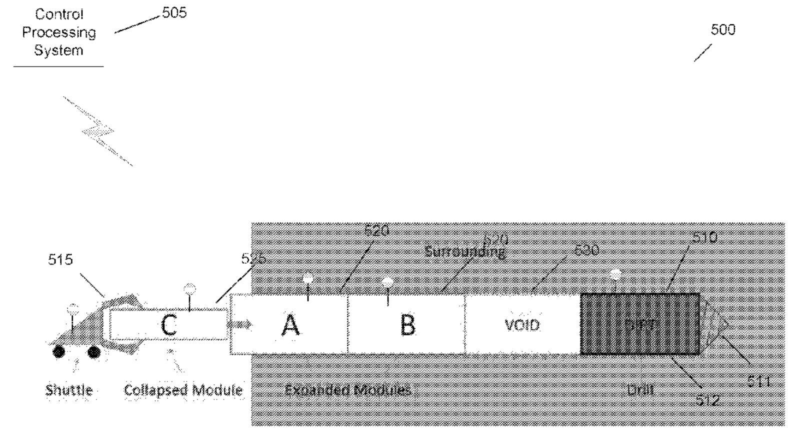

FIG. 4

(57) **Abstract**: A robotic drilling system for creating tunnels and conduits is disclosed. The robotic drilling system can include a drill module, a frame module, and/or a shuttle module. The drill module can include a drill and is used to drill into a material to create a void that is the volume of an uncompressed frame module. Frame modules can support the sides of a conduit created by the drill module. Frame modules can be inserted into a conduit in a compressed state and are moved through uncompressed frame modules into a void. A frame module can then be expanded into an uncompressed state that supports the walls of the void. In many embodiments, a shuttle module is used to move the frame modules into position. The shuttle module can also be used to remove shredded material created by drilling by the drill module.

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Modular Tunneling and Boring Robotic Systems

FIELD OF THE INVENTION

[0001] This invention relates to horizontal drilling of conduits to place cables underground. More particularly, this invention relates to a systems and methods that use robotic modules to perform horizontal drilling

BACKGROUND

[0002] Creating a conduit in the ground through which a cable can pass is a difficult task that requires the displacement of significant amounts of soil, rock, and other terrain. Typically, the creation of the conduit involves digging a trench, inserting any walls or other support for the conduit, laying the cable into the conduit, covering the conduit with excavated dirt, and replacing any structures that were damaged or removed during the trench digging process. An alternative process is a horizontal drilling process in which a smaller hole is made at one end of the desired conduit and then a horizontal hole is bored using a drilling process. Thus, a horizontal drilling process causes less disruption to the surrounding environment.

[0003] However, there are numerous problems associated with a horizontal drilling process. In particular, one problem is that a conventional horizontal drilling process is similar to a conventional vertical drilling process in which a drill pierces and pulverizes the ground beneath it. In the vertical drilling process, the resulting shredded materials are removed using a screw or auger. One issue with the use of an auger or screw in a vertical drilling process is that friction between the walls of the hole and whatever is being used to transport materials to the surface increases with the drill's depth making it harder to remove shredded material the farther down the hole is drilled. In a horizontal drilling process, friction becomes an even larger problem because the direction of drilling is not the same as the direction of gravity, so extra horizontal force is required to remove the material as the drilling continues. As an added complication in horizontal drilling, there is also a risk of the tunnel collapsing if the ceiling is not reinforced. Thus, those skilled in the art are constantly striving for improvements in the horizontal drilling process that will make the use of horizontal drilling a more viable alternative for placing of underground conduits.

SUMMARY OF THE INVENTION

[0004] The above discussed and other problems are solved and an advance in the art is made by a robotic drilling system that performs horizontal drilling in accordance with various embodiments of the invention. A robotic system that performs horizontal drilling in accordance with some embodiments of the invention includes modules that perform the drilling and a control system that the controls in modules.

[0005] The modules including a frame module, a drill module, and a frame module. The frame module has a body capable of expanding from a compressed state to an uncompressed state. The body has a larger cross section in the uncompressed than the cross section of the body in the compressed state. The drill module includes a drill portion at a first end of the module. The drill module drills into a material to create a void having a volume at least as great as a volume of an uncompressed frame module. The shuttle module inserts a frame module in a compressed state into the void created by the drill module.

[0006] The control system includes a processor, a memory and instructions stored in the memory. The instructions direct the processor to communicate with the modules to perform the horizontal drilling operation. In accordance with many embodiments, the horizontal drilling operation is performed in the following manner. The drill module horizontally drills into a material to create a void that has a volume that is at least equal to a volume of the frame module in the compressed state. The frame modules is inserted in a compressed state into the void using the shuttle module. The frame modules is then expanded the frame module from the compressed state into the uncompressed state in the void.

[0007] In accordance with many embodiments of the invention, the drill module further includes a storage portion in the second end of the drill module to store shredded material created by the drill. In accordance with some of these embodiments, the instructions to perform the drilling operation may also include instructions to communicate with the shuttle module to cause the shuttle module to remove the shredded material from the storage portion of the drill module. In a number of these embodiments, the drill module further includes an auger in the storage portions that transfers material from a front end of the storage portion behind the drill to a back end of the storage compartment.

[0008] In accordance with some embodiments of the invention, the frame module further includes an inflation system for changing the frame module from a compressed to an uncompressed state. In accordance with a number of these embodiments, the inflation system is an air bladder. In many embodiments, the frame module also includes a coupling on an end of the frame module for connecting to an adjacent end of a second frame module.

[0009] In accordance with many embodiments of the invention, the shuttle module includes wheels that extend out of the body of the shuttle module and an electronic servo system connected to the wheels for turning the wheels for propulsion.

[0010] In accordance with a number of embodiments of the invention, the frame modules include passive wheels that extend out of the body of the frame module. In accordance with some embodiments, the interior of the body of the frame module includes tracks that the shuttle module travels along.

[0011] In accordance with some embodiments, the drill module includes a sensor system that sends information to the control system for use in path planning. In accordance with many embodiments, the drill module further includes a motor that powers the drill.

[0012] In accordance with some embodiments, the control system communicates with the plurality of modules wirelessly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 conceptually illustrates a “FIFO” method used in conventional horizontal drilling techniques.

[0014] FIG. 2 conceptually illustrates a “FILO” method used in a horizontal drilling process in accordance with an embodiment of this invention.

[0015] FIG. 3 conceptually illustrates the use of the “FILO” method in a horizontal drilling in accordance with an embodiment of the invention

[0016] FIG. 4 illustrates components of a horizontal drilling system in accordance with an embodiment of the invention.

[0017] FIG. 5 illustrates components of a processing device in a component of a horizontal drilling system in accordance with an embodiment of the invention.

[0018] FIG. 6 illustrates the removal of dirt after the insertion of a module in a void in a drilled tunnel in accordance with an embodiment of the invention.

[0019] FIG. 7 illustrates a drilling module boring in a tunnel in accordance with an embodiment of the invention.

[0020] FIG. 8 illustrates another view of a drilling module boring in a tunnel in accordance with an embodiment of the invention.

DETAILED DISCLOSURE

[0021] Turning now to the drawings, some embodiments of a robotic system and method for boring a cable conduit are disclosed. In accordance with several embodiments of the invention, a horizontal drilling system for boring a cable conduit includes three types of modules: a robotic drill module, a frame module, and a robotic shuttle module. The robotic drill module can include a drill portion and a storage portion. The drill portion drills through the ground creating the channel for the conduit. The shredded material produced by this process is stored inside of the storage portion. In accordance with many of the embodiments, the storage portion of the drill module is capable of storing a volume of shredded material that is approximately equal to the volume of one expanded frame module (as described in more detail below). An auger runs through the middle of the storage portion from the head of the drill in the drill portion in accordance with many embodiments. In accordance with some of these embodiments, the auger transfers the shredded material from the head of the drill portion to the back of the storage portion of the drill module. The connection of the auger to the head of drill in accordance with a number of these embodiments allows for a continuous flow of shredded material during the drilling process from the head of the drill to the back of the storage compartment.

[0022] In accordance with some embodiments, the frame modules create the structure of the tunnel. The frame modules have a hollow, flexible, cylindrical design in accordance with many embodiments. The frame modules are lined up in the tunnel to form a pipe or conduit in accordance with some embodiments. The adjacent ends of adjoining frame modules in the conduit are connected by couplings that may be either a mechanical or a magnetic apparatus in accordance with various embodiments of the invention. In order to build the tunnel, each frame module compresses to a point that a compressed frame module can fit through a conduit formed by an uncompressed frame module in accordance with some embodiments of the invention.

[0023] In accordance with many embodiments, the shuttle module is used for two purposes: to shuttle frame modules to the front of the tunnel and to remove shredded material from the drill module at the front of the tunnel. In accordance with some embodiments, the shuttle module has a long cylindrical design that allows the shuttle module to traverse the uncompressed frame modules and place compressed frame modules in the tunnel; and to carry dirt from the front of the tunnel. In accordance with a number of embodiments, the shuttle module is driven by electric servos connected to rubber rollers that extend out of the of the shuttle module. Shredded material can be evacuated by the shuttle module connecting to the drill module in accordance with many embodiments. The auger in the drill module can also be used to move shredded material from the drill module to the shuttle module in accordance with a number of embodiments.

[0024] In accordance with several embodiments, the modules are controlled by a control system via wireless connections. In accordance with certain embodiments, each module includes a processing system that receives instructions from the control system and operates the module to perform the instructions. In accordance with some other embodiments, the control system is a processing system that executes instructions to perform the drilling process and transmits signals via the wireless connections to operate the systems in each module.

[0025] In accordance with many embodiments, a procedure for expanding the tunnel by one frame module is performed in the following manner. The starting state is a tunnel made of previously expanded frame modules. The drill module bores into the end of the tunnel using the drill portion to create a void of sufficient volume for one uncompressed frame module in between the end of the uncompressed frame modules and the robotic drill module. At this point, the storage portion of the drill module is at full capacity. The shuttle module then pushes a compressed frame module into the void. The compressed frame module is restored to an uncompressed state in the void and couples to the end of the uncompressed modules. The shuttle unit then traverses the newly attached frame module to reach the drill module. The shuttle module then removes shredded material from the storage portion of the drill module and returns back to the opening of the conduit along the uncompressed frame modules.

[0026] While much of the discussion that follows relates to fully automated robotic systems that are particularly suited to the construction of conduits for cabling, similar systems can be utilized to construct larger tunnels. In a number of embodiments, people can shuttle shredded material and push compressed frame modules into place as the drill modules bores into the end of the tunnel. Various components and processes performed by systems when performing methods for boring conduits in accordance with different embodiments of this invention are described in more detail below.

OVERVIEW OF TUNNELING CONCEPTS

[0027] A typical tunneling process for vertical and/or horizontal drilling can be described as a First In First Out (FIFO) process. A convention FIFO tunneling process commonly used in the prior art is shown in FIG. 1. In a FIFO tunneling process, the drilling tool A is the first item being sent to create the tunnel and will be pushed through until it exits. Anything trailing behind the drilling tool A, such as an auger or a cable, will exit in the order that it entered the tunnel. If the drilling tool A needs to pull a cable through the ground as a tunnel is created, the amount of force required by the drilling tool increases with tunnel depth due to the friction between the cable and the ground. In the shown embodiment, drilling tool A is inserted first and shreds material as the drilling tool enters the ground. Frame modules B, C, and D are then sequentially placed in the tunnel formed by Drilling Hole A. As the drill tunnels deeper, the first frame module (B) also descends deeper in the hole and the next frame module (C) is placed in the tunnel behind first frame module (B). The process is repeated with another frame module (D) being placed in the tunnel behind frame module (C). The module being inserted pushes the previously inserted modules deeper into the tunnel. Thus, more energy is needed to keep pushing first frame module (B) and the subsequent frame modules (C and D) into the tunnel as the depth of the tunnel increases and/or number of modules being pushed increases.

FIRST IN, LAST OUT TUNNELING PROCESSES

[0028] To assuage the problem of increased work with depth, a discrete “First In, Last Out” (FILO) process can be used to alleviate some of the problems with friction in accordance with some embodiments of the invention. A conceptual diagram of a FILO tunneling processing in accordance with an embodiment of this invention is shown in FIG. 2. In a FILO tunneling procedure, short tube modules (A-D) are inserted into the ground one at a time. In the FIFO process described above, each module (B-D) is used to push the previous one in deeper. In FILO, the first module (A) is inserted. The next module (B) is compressed, travels through the first module, and de-compresses on the other end extending the tunnel. This process is repeated until the tunnel for the remainder of the modules (C-D). In this way, each module only has to overcome the friction force associated with one module to extend the tunnel rather than the friction force needed to move the entire chain of modules further into the tunnel. A FILO process is similar to that of putting on a stocking. If the stocking is simply pulled onto the leg (FIFO process), the friction between the stocking and leg becomes too great and the fabric tears. This situation reflects the possibility of a cable being dragged through a tunnel breaking due to the large forces being exerted at the end being pulled. On the other hand, a FILO process is similar to the situation in which the stocking is inverted or rolled before being placed over the leg, the stocking then just needs to be unrolled up the leg, requiring a constant but small force as it is unrolled.

[0029] A discrete version of a FILO tunneling can be applied by horizontal robotic drilling systems in accordance with various embodiments of the invention. In the FILO tunneling process, tunnel segments enter the tunnel collapsed (compressed) and will expand (decompress) upon exiting in a newly excavated area of the tunnel. As noted above, the implementation of the FILO method using robotic systems is not limited to creating channels for cables and fiber optic lines. For example, the FILO tunneling concept may be applied on a larger scale in any other situation that requires the rapid creation of a tunnel, such as (but not limited to) a tunnel through debris in a collapsed or collapsing building. A more specific design for a tunneling system using A FILO tunneling technique is described in the following section with reference to FIGS. 3 and 4.

ROBOTIC TUNNELING SYSTEMS

[0030] A procedure for expanding a tunnel by one frame module in a FILO tunneling process in accordance with an embodiment of the invention is shown in FIG. 3. The starting state is a tunnel made of previously expanded frame modules (A and B) in the tunnel. A robotic drill module bores through the ground creating a void big enough for one frame module in between the end of the expanded frame modules and the robotic drill module. The shredded material created by the boring accumulates at the back of the robotic drill module. A new module (C) (Not Shown) may now be inserted into the void to support the wall of the tunnel.

[0031] A horizontal drilling system that uses the FILO method described above in accordance with an embodiment of the invention is shown in FIGS. 4-6. In the illustrated embodiment, the horizontal drilling system 500 includes three types of modules: a robotic drill module 510, a frame module (520, 525), and a robotic shuttle module 515. The robotic drill module 510 includes a drill portion 511 and a storage portion 512. The drill portion 511 drills through the ground creating the channel for the conduit. The shredded material produced by this process is stored inside of the storage portion 512. In accordance with many of the embodiments, the storage portion 512 of the drill module 510 is capable of storing a volume of shredded material that is approximately equal to the volume of one expanded frame module 520 (as described in more detail below). In many embodiments, an auger (not shown) runs through the middle of the storage portion 512 from the head of the drill in the drill portion 511. In accordance with some of these embodiments, the auger transfers the shredded material from the head of the drill portion 511 to the back of the storage portion 512 of the drill module 510. The connection of the auger to the head of the drill in accordance with a number of these embodiments allows for a continuous flow of shredded material during the drilling process from the head of the drill to the back of the storage compartment. As can readily be appreciated, the specific implementation of the robotic drill module largely depends upon the requirements of a specific application and typically includes a variety of sensors to assist with path planning and monitoring drilling, communication modules to maintain telemetry with operators and/or propulsion systems that can include (but are not limited) electric motors and/or motors driven by hydrocarbon fuel sources.

[0032] In accordance with several embodiments, the frame modules 520 create the structure of the tunnel. The frame modules 520 have a hollow, flexible, cylindrical design in accordance with many embodiments. The frame modules 520 can be lined up in the tunnel to form a pipe or conduit in accordance with some embodiments. The adjacent ends of adjoining frame modules 520 in the conduit can be connected by couplings (not shown) that may be either mechanical or magnetic couplings. Specific coupling techniques are typically determined by the requirements of a given application. In order to build the tunnel, each frame module compresses to a point that a compressed frame module 525 can fit through a conduit formed within an uncompressed frame module 520 in accordance with some embodiments of the invention. In accordance with many embodiments, the compression is performed by folding a frame using actuators in joints that move between a compressed and uncompressed position. In several other embodiments, the expansion of the compressed frame module may be performed by an air bladder that is uninflated in the compressed position and inflates to cause segments of the module to snap into position in an uncompressed state. The expansion of the compressed frame module 520 can also be performed manually and/or by application of force by the shuttle module 515,

[0033] In accordance with many embodiments, the shuttle module 515 is used for at least one of two purposes: to shuttle uncompressed frame modules 525 to the front of the tunnel and to remove shredded material from the drill module 510 at the front of the tunnel. In accordance with some embodiments, the shuttle module 515 has a long cylindrical design that allows the shuttle module to traverse the uncompressed frame modules 520 and place compressed frame modules 525 in the tunnel; and to carry dirt from the site of drilling within the tunnel. In accordance with a number of embodiments, the shuttle module 515 is driven by electric servos connected to rollers that extend out of the of the shuttle module. The rollers can be rubber, metal, and/or any other material(s) appropriate to the requirements of a given application. In certain embodiments, the frame modules include one or more tracks and the shuttle module is configured to travel along the one or more tracks of the frame modules. Dirt can be evacuated by the shuttle connecting to the drill module. Designs of the shuttle module 515 in accordance with various embodiments of the invention are shown in FIGS. 7 and 8. As can readily be appreciated, the specific form factor the shuttle is largely dependent upon the requirements of a given application. The auger in the drill module 510 is also used to move the dirt from the drill module 510 to the shuttle module 515 in accordance with a number of embodiments.

[0034] In accordance with certain embodiments, the various modules 510, 515, 520, and 525 are controlled by control system 505 via one or more wireless connections (illustrated by lightning). In accordance with some embodiments, each module includes a processing system (not shown) that receives instructions from the control system and operates the module to perform the instructions. In accordance with many other embodiments, the control system 505 is a processing system 600 (shown in FIG. 6) that executes instructions to perform the drilling process and transmits signals via the one or more wireless connections to operate the systems in each module. In accordance with a number of embodiments, each module may include processing systems that autonomously control the process of the module and/or communicate with a remote processing system that assists with coordination of the activities of the modules.

PROCESSES FOR TUNNELING USING FRAME MODULES

[0035] In accordance with some embodiments, a procedure for expanding the tunnel by one frame module is performed in the following manner. The starting state is a tunnel made of previously expanded frame modules 520. The drill module 510 bores into the end of the tunnel using the drill portion 511 to create a void 530 of sufficient volume for one uncompressed frame module 520 in between the end of the uncompressed frame modules 520 and the robotic drill module 510. At this point, the storage portion 512 of the drill module is at full capacity. The shuttle module 515 then pushes a compressed frame module 525 into the void. The compressed frame module 525 is restored to an uncompressed state 520 in the void 530 and coupled to the end of the uncompressed modules 520. In certain embodiments, the shuttle module 515 can then traverse the newly attached uncompressed frame module 520 to reach the drill module 510. The shuttle module 515 can remove shredded material from the storage portion 511 of the drill module 510 and return back to the opening of the conduit along the uncompressed frame modules 520. As noted above, the motion of the shuttle module can be constrained by one or more tracks within the frame modules.

[0036] Although, a specific horizontal robotic drilling system and process for using the system are described above with reference to FIGS. 4-6, other horizontal drilling systems may include these and other modules performing the same and/or other processes in accordance with some other embodiments of the invention. In addition, the robotic drilling systems are not constrained to horizontal drilling and may be used in a variety of angles relative to the direction of gravity. When the direction of drilling approaches parallel to the direction of gravity, the exterior surfaces of the frame modules may include protrusions to facilitate lodgment of the frame modules at specific locations within a conduit or tunnel.

[0037] The mechanically intelligent design of the horizontal drilling system shown in FIGS. 4-6 is an effective technique for constructing a network of tunnels using a fleet of autonomous robots. The FILO tunneling process used in accordance with some embodiments of this invention has the potential to be both low in mechanical complexity and required power. In the robotic drilling systems described above with reference to FIGS. 4-6, only the drill and shuttle modules require the power to move themselves rather than the power to move all of the modules used to make the entire tunnel. This efficiency not only can reduce cost but it may also increase the safety and reliability of the system. Examples of the types of shuttle module and frame modules that could be utilized in the construction of conduits and/or any of the other varieties of structures described herein such as (but not limited to) pipes in free space and towers in accordance with various embodiments of the invention are illustrated in FIGS. 7 and 8. As can readily be appreciated the specific drill modules, frame modules, and/or shuttle modules utilized in a robotic drilling system in accordance with various embodiments of the invention largely depend upon the specific application of the robotic drilling system

[0038] While specific examples of robotic drilling systems are described above with reference to FIGS. 1 – 8 any of a variety of implementations of robotic drilling structures can be utilized as appropriate to the requirements of specific applications. In certain embodiments, similar robotic systems can be utilized in the maintenance of constructed conduit by eliminating a compromised frame module and shuttling a new frame module into the resulting void. The replacement module can then be expanded into an uncompressed state and the conduit stabilized.

DESIGN MODIFICATIONS

[0039] In accordance with various embodiments of the invention, the following modifications may be made without departing from aspects of the invention.

[0040] 1. No Shuttle Module: To eliminate the need for the shuttle module, a different type of propulsion through the tunnel can be utilized. In order to eliminate the shuttle module in accordance with some embodiments of the invention, each one of the frame modules could have a very small servo or mechanical transmission going through the frame module. An outside motor or power supply could power or turn each one of the motors/gear trains in each frame module during travel through the tunnel. By having distributive propulsion in each module, it would be very easy to move a very large cable through the tunnel and/or additional frame modules. Also, the need of a shuttle module to push the compressed modules to the front would no longer be needed. Concerns that arise with the lack of a shuttle module include, but are not limited to, the need for mechanical or electrical alignment between frame modules, price of each frame module, and increased complexity of frame modules.

[0041] 2. Rigid Frame Modules: Instead of a flexible frame module that uses passive expansion, a rigid frame module could be designed that requires a mechanical expansion in accordance with some embodiments. In accordance with some of these embodiments, the mechanical expansion could be performed by a spring or other biasing mechanism. In accordance with some other embodiments, the mechanical expansion may be performed by a hydraulics system in the frame module. The advantage to a rigid frame module is increased strength. The increased strength may allow for no removal of shredded material or less removal if the expansion process is now capable of compressing the material (including the shredded material) around module. Concerns with rigid frame modules include, but are not limited to, increased complexity of frame modules and increased complexity with the expansion process. Furthermore, the drill module may need to interface with the frame modules to perform the expansion process in accordance with some of these embodiments.

[0042] 3. Frame Modules with Passive Rollers: The frame modules may include passive rollers. In some embodiments, the passive rollers extend out of the outer surface of a module and/or out of an inner surface that defines at least a portion of a conduit within an expanded module. The passive rollers reduce friction caused as a shuttle module pulls a frame module through the system and/or as a cable is pulled through the formed tunnel.

[0043] While the above contains descriptions of many specific optional aspects of the invention, these should not be construed as limitations on the scope of the invention, but rather as an example of different configurations thereof. For example, the frame modules described above need not be configured to expand from a compressed to an uncompressed state. Instead, the frame modules could be sequenced in sizes of increasingly smaller cross section. Furthermore, similar construction techniques can be utilized to build pipes and/or towers in free space. Each section of piping or framing can be shuttled through previously constructed structure using a shuttle module, expanded, and fixed into place. Accordingly, the scope of the invention should be determined not by the examples illustrated, but by the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A robotic drilling system comprising:

a plurality of modules including:

a frame module including a body capable of expanding from a compressed state to an uncompressed state having a larger cross section than the cross section of the frame module in the compressed state,

a drill module that includes a drill portion at a first end where the drill module drills into a material to create a void having a volume at least as great as a volume of an uncompressed frame module, and

a shuttle module that inserts a frame module in a compressed state into the void created by the drill module; and

a control system that includes a processor, a memory and instructions stored in the memory that direct the processor to communicate with the plurality of modules to:

horizontally drill into a material using the drill module to create a void that has a volume that is at least equal to a volume of the frame module in the compressed state,

insert the frame module in a compressed state into the void using the shuttle module, and

expand the frame module from the compressed state into the uncompressed state in the void.

2. The robotic drilling system of claim 1 wherein the drill module further includes a storage portion in the second end of the drill module to store shredded material created by the drill.

3. The robotic drilling system of claim 2 wherein the instructions stored in memory direct the processor to communicate with the shuttle module to cause the shuttle module to remove the shredded material from the storage portion of the drill module.

4. The robotic drilling system of claim 2 wherein the drill module further includes an auger in the storage portions that transfers material from a front end of the storage portion behind the drill to a back end of the storage compartment.

5. The robotic drilling system of claim 1 wherein the frame module further includes an inflation system for changing the frame module from a compressed to an uncompressed state.

6. The robotic drilling system of claim 5 wherein the inflation system is an air bladder.

7. The robotic system of claim 5 wherein the frame module includes a coupling on an end of the frame module for connecting to an adjacent end of a second frame module.

8. The robotic system of claim 1 wherein the shuttle module includes wheels that extend out of the body of the shuttle module and an electronic servo system connected to the wheels for turning the wheels for propulsion.

9. The robotic system of claim 1 wherein the frame modules include passive wheels that extend out of the body of the frame module.

10. The robotic system of claim 1 wherein the interior of the body of the frame module includes tracks along which the shuttle module travels.

11. The robotic system of claim 1 wherein the drill module includes a sensor system that sends information to the control system for use in path planning.

12. The robotic system of claim 1 wherein the drill module further includes a motor that powers the drill.

13. The robotic system of claim 1 wherein the control system communicates with the plurality of modules wirelessly.

14. A method for performing a horizontal drilling operation to create a conduit using a robotic system that includes a plurality of modules and a control system that controls the plurality of modules, comprising:

horizontally drilling into a material using a drill module to create a void that has a volume that is at least equal to a volume of a frame module in a compressed state;

inserting a frame module in a compressed state into the void; and

expanding the frame module into an uncompressed state in the void.

15. The method of claim 14, wherein the inserting of the frame module is performed using a shuttle module.

16. The method of claim 14 wherein the frame module is inserted into the void through a conduit formed within a second frame module, where the second frame module is in an uncompressed state.

17. The method of claim 14 further comprising storing shredded material created by the drilling in a storage portion of the drill module.

18. The method of claim 17 further comprising removing shredded material created by the drilling from the storage portion using a shuttle module.

19. The method of claim 17 further comprising moving the shredded material from a front end of the storage portion proximate the drill to a back of the storage portion using an auger.

20. A method for performing a horizontal drilling operation to create a conduit using a robotic system that includes a plurality of modules and a control system that controls the plurality of modules, comprising:

horizontally drilling into a material using a drill module to create a void that has a volume of a frame module in an uncompressed state;

inserting a frame module in a compressed state into the void through a conduit formed within a second frame module using a shuttle module, where the second frame module is in an uncompressed state;

expanding the frame module into an uncompressed state in the void; and

coupling an end of the uncompressed frame module to an adjacent end of the second frame module.

21. The method of claim 20 further comprising:

removing shredded material from the void using the shuttle module.

22. The method of claim 20 further comprising

storing shredded material in a storage portion of the drill module during the horizontal drilling; and

removing the shredded material from the storage portion of the drill module using the shuttle module; and

transporting the shredded material out of the conduit using the shuttle module.

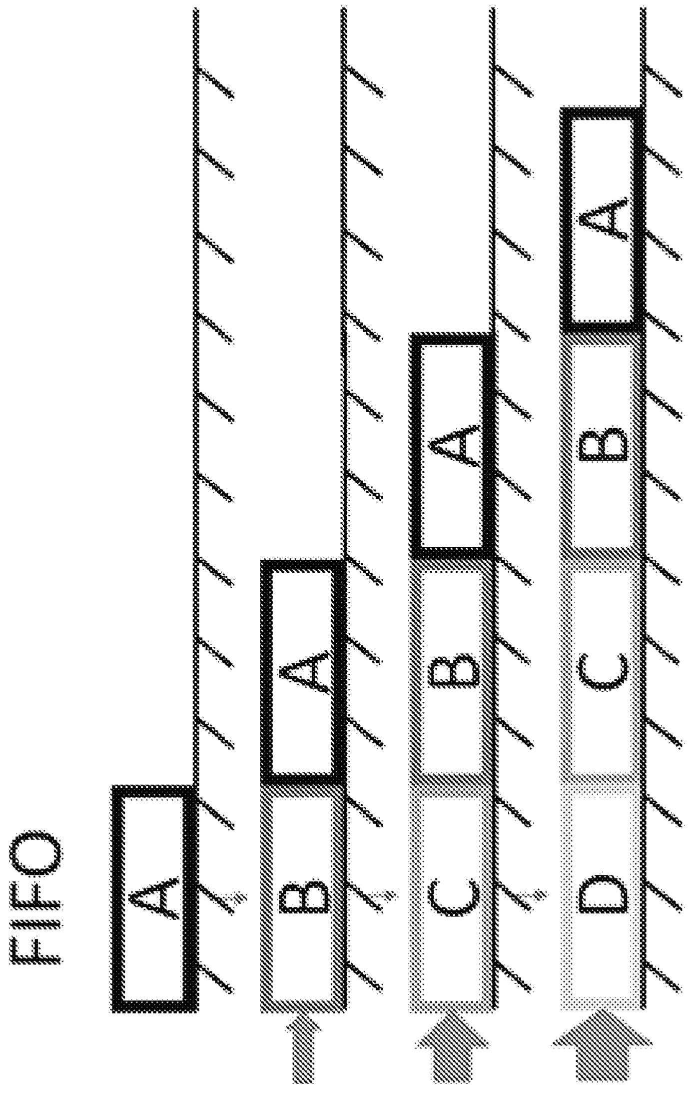

FIG. 1

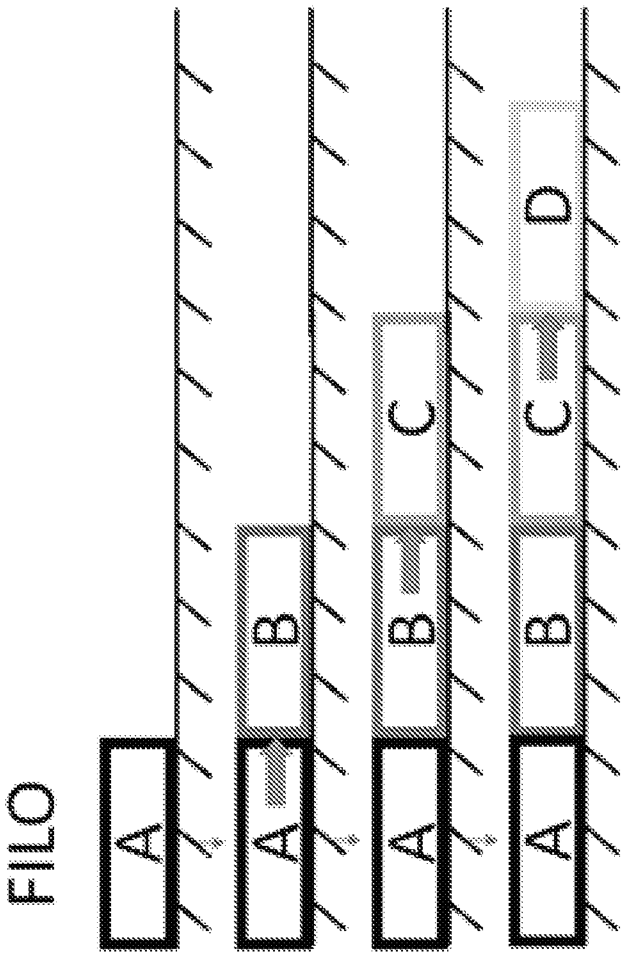

FIG. 2

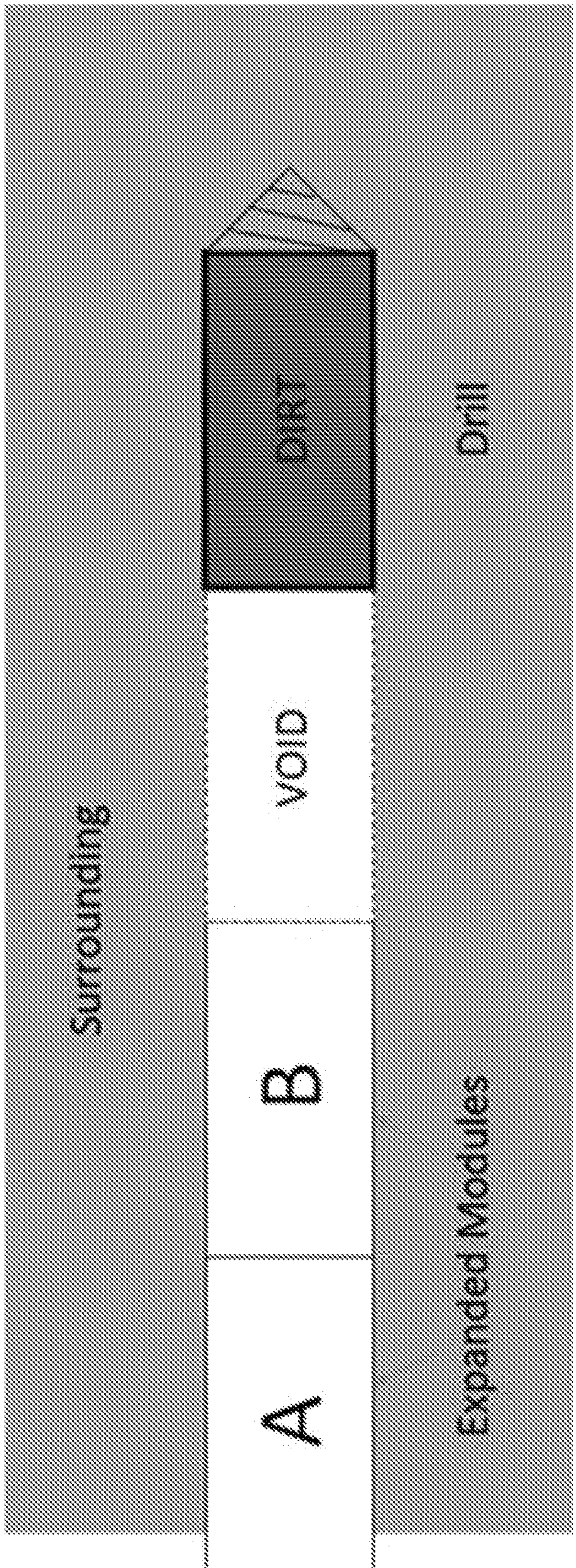

FIG. 3

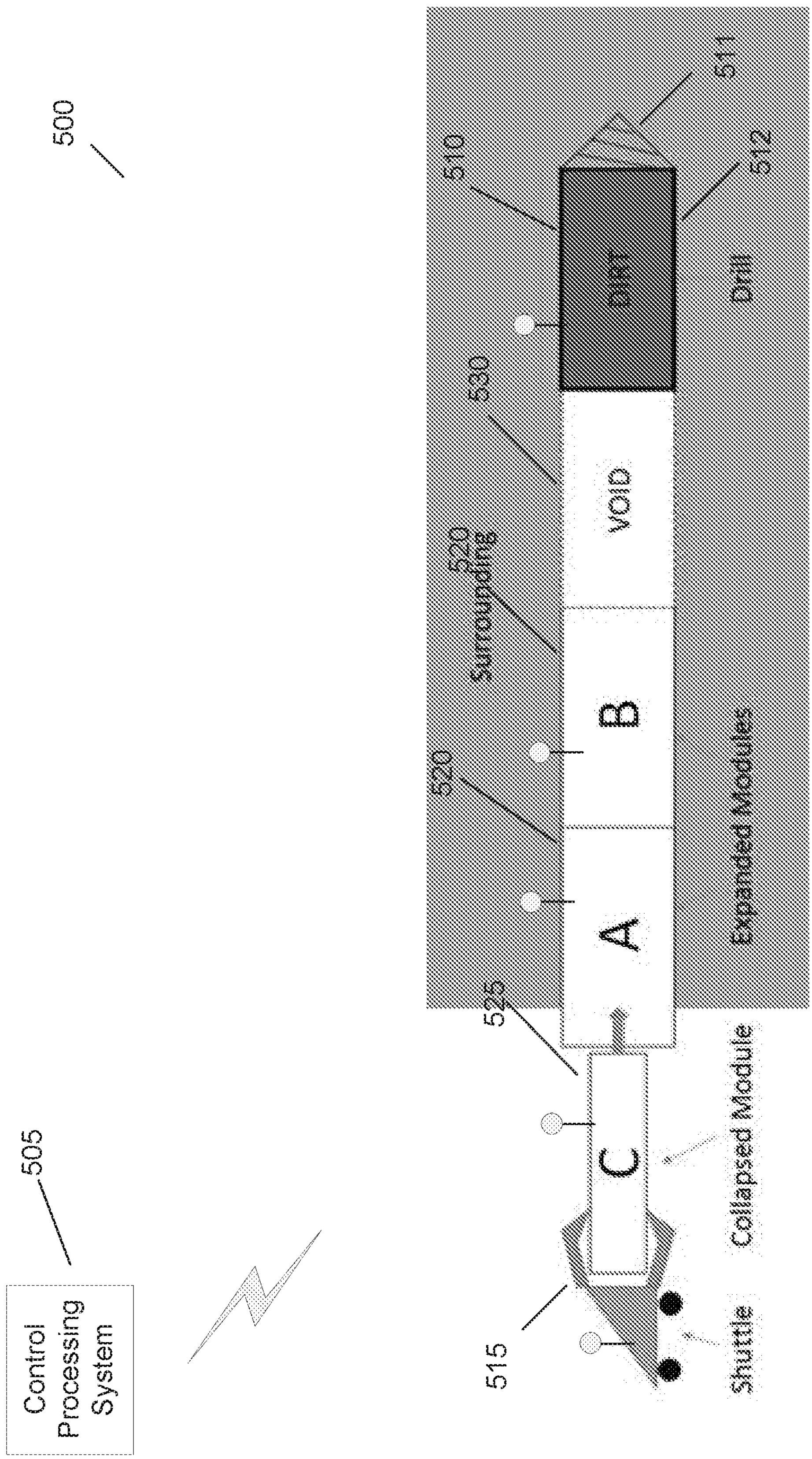
500
505
Control Processing System
515
Shuttle
Collapsed Module
C
525
A
B
520
520
Surrounding
Expanded Modules
530
VOID
510
DIRT
Drill
511
512

FIG. 4

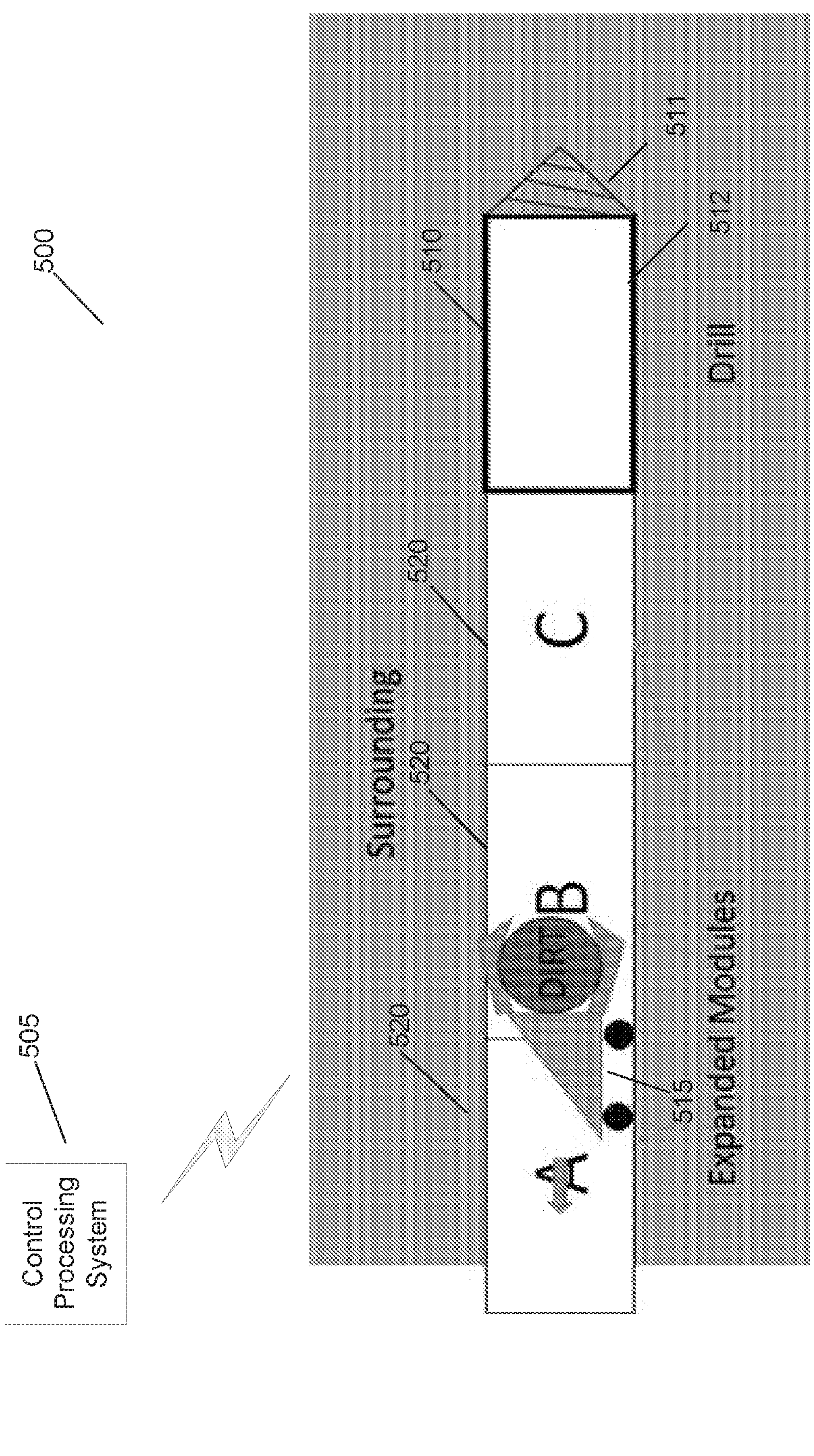
500
505
Control Processing System
510
511
512
515
520
520
520
Surrounding
Drill
Expanded Modules
A
B
C
DIRT

FIG. 5

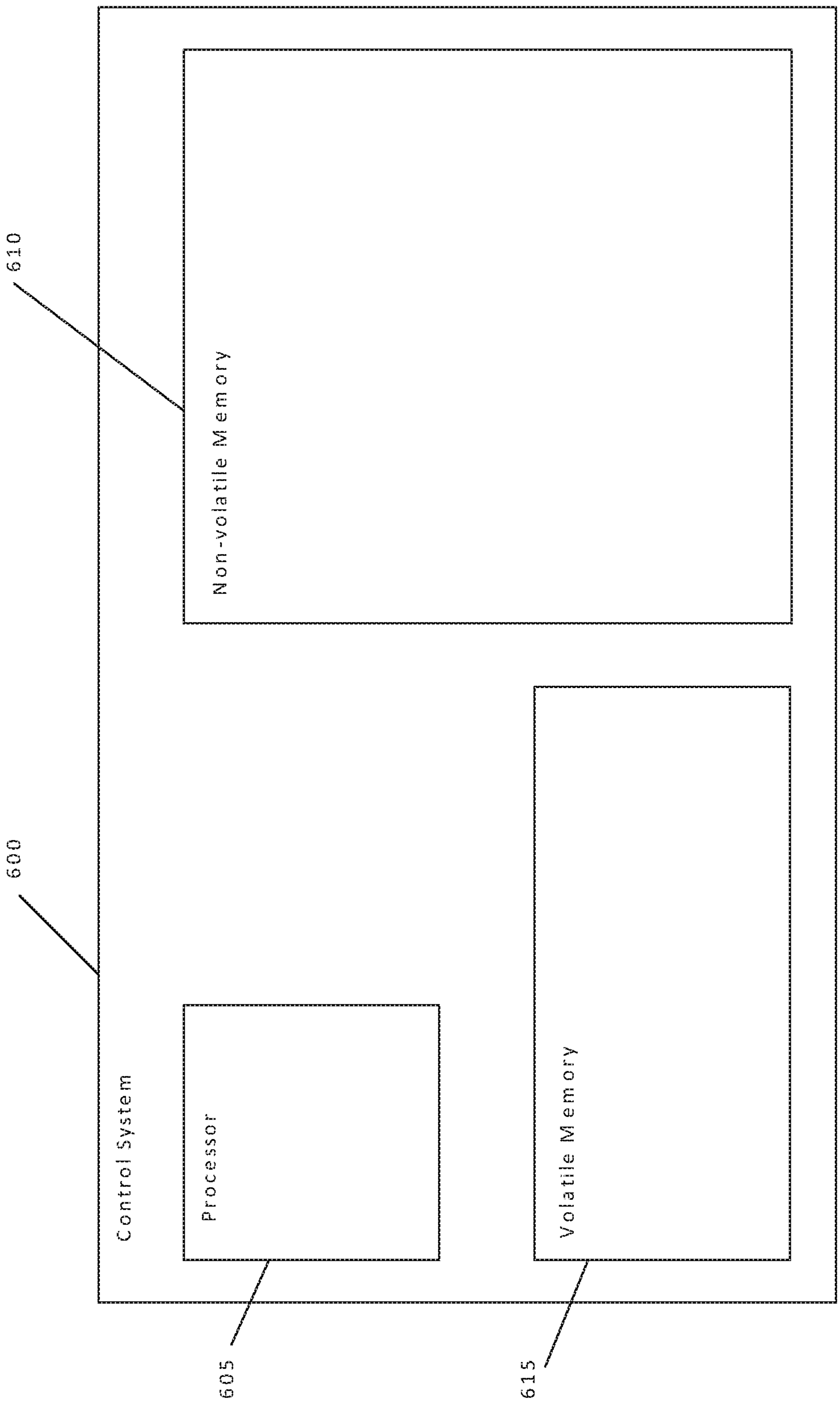
610
Non-volatile Memory
600
Control System
Processor
Volatile Memory
605
615

Figure 6

FIG. 6

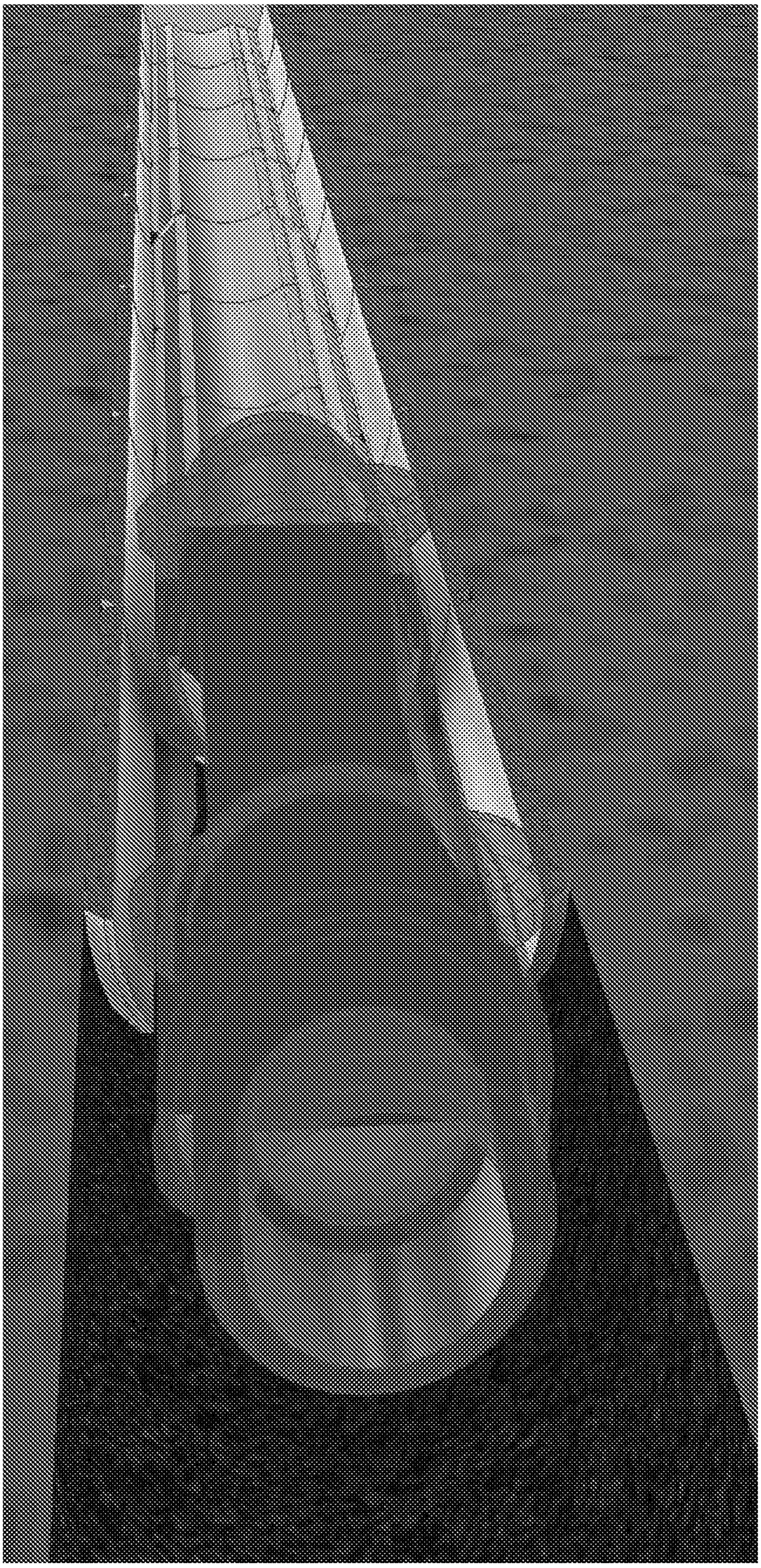

FIG. 7