PROPULSION MECHANISM FOR ENDOSCOPIC SYSTEMS

FIELD OF THE INVENTION

This invention relates to an apparatus useful in medical and non-medical applications to introduce accessory devices into collapsible and non-collapsible, body cavities or canals, pipes, lumens and other generally tubular spaces or environments. More particularly, the invention relates to a propulsion system for endoscopic systems.

BACKGROUND OF THE INVENTION

An endoscope is any instrument used to obtain a view of the interior of a patient's body using a variety of means to capture and transmit the view to an observer. Endoscopes can also be used to perform a variety of diagnostic and interventional procedures such as biopsies and other small surgical procedures. Examples of endoscopes include: a colonoscope used within the colon, a gastroscope used inside the stomach, and a bronchoscope used within the trachea and bronchi. Endoscopes are often inserted into body cavities or lumens via natural orifices but can also be inserted into incisions to gain access to areas of the body where no natural entrance exists.

Traditional endoscopes consist of a rigid or flexible rod or shaft with a means of collecting and transmitting an image from inside the patient's body. The rod or shaft is inserted and pushed to the location of interest. The rod or shaft typically surrounds a number of pathways used to house fiber optic cables and route instruments, catheters, devices, gasses, liquids and other substances in and out of the area of interest.

Traditional endoscopes require a minimal rigidity for successful insertion and work well when the body cavity or canal, or other lumens having curves and turns. However, when it is constricted, convoluted and consists of many curves, as is the case with the colon, it can be difficult or impossible to push the endoscope to its desired location. Steerable articulating endoscopes are often used to make navigation of turns easier; however, the increased friction associated with each additional turn limits the number of turns that can be navigated successfully and ultimately limits the distance an endoscope can be introduced into the patient's body. In addition, the increased force required to complete more turns and corners raises the risk of complications such as bowel perforation as well as the discomfort and pain experienced by the patient. It would be useful to have an apparatus for endoscopic medical procedures that can navigate in such environments and can overcome the physical and procedural limitation of traditional endoscopes. It would further be useful if such an apparatus were self-propelled.

Endoscopic devices may also be utilized in non-medical or commercial and industrial applications to obtain views from or introduce instruments or devices into generally tubular spaces or environments such as lumens, sections of pipe or other structures, which may have a number of curves and turns. Such tubular spaces or environments may be partially occluded or have buildup on their interior surfaces and thus present a irregular internal shape or diameter. To navigate through such spaces and environments, it would be useful to have a device or apparatus that can adapt to the internal shape or diameter of the space or environment into which it is introduced and of further use if the apparatus were self-propelled.

SUMMARY OF THE INVENTION

The invention in it various embodiments is a propulsion apparatus that can be used to transport accessory devices within body cavities or canals, sections of pipe, lumens, and other generally tubular spaces and environments and is generally comprised of a toroid and a powered or motorized frame. The motion of the toroid can be powered or unpowered and the direction and speed may be controlled.

In an embodiment of the invention, the apparatus is comprised of a toroid and a frame. The toroid is a fluid-filled, enclosed ring formed of a flexible material. The enclosed ring defines a central cavity, having an interior volume and presenting an exterior surface and an interior surface which move continuously in opposite directions when the apparatus is in motion.

In one embodiment, the frame is formed of a support structure, a housing structure and a series of at least two sets of interlocking rollers or skids located on the support and housing structures. The support structure is located within the interior volume of the enclosed ring. The housing structure is concentrically and coaxially located relative to the support structure and disposed in the central cavity of the enclosed ring. The rollers or skids are located so as to maintain the two structures in a fixed spatial relationship with the flexible material of the enclosed ring being positioned between the two structures and the rollers or skids located thereon.

In another embodiment, the frame is formed of a support structure located within the interior volume of the enclosed ring and a series of at least two sets of interlocking rollers or skids located on the support structure. The rollers or skids are located so as to maintain the flexible material of the enclosed ring between them.

In other embodiments of the invention, the apparatus is a propulsion apparatus for transport of accessory devices. The apparatus is comprised of a toroid and a powered frame. The toroid is a fluid-filled, enclosed ring formed of a flexible material. The enclosed ring defines a central cavity and has an interior volume. The powered frame is formed of a support structure and housing structure or a support structure alone. A series of at least two sets of interlocking rollers or skids located on the support and housing structures or on the support structure in the case there is no housing structure. The support structure is located within the interior volume of the enclosed ring. The housing structure is concentrically and coaxially located relative to the support structure and disposed within the central cavity of the enclosed ring. The rollers or skids are located so as to maintain the two structures in a fixed spatial relationship with the flexible material of the enclosed ring being positioned between the two structures and the rollers or skids located thereon. The rollers may be connected to a power source and when powered provides a motive, directional force to the flexible material.

In its various embodiments, the apparatus of the invention may further comprise at least one accessory device. Depending upon whether the apparatus is to be used for medical or non-medical applications, the at least one accessory device may be selected from the group consisting of endoscopes, cameras, video processing circuitry, fiber optic cables, electronic communication cables, lasers, surgical instruments, medical instruments, diagnostic instruments, instrumentation, sensors, stent catheters, fluid delivery devices, drug delivery devices, electronic devices, tools, sampling devices, assay devices, articulating segments, cables to articulate the articulating segments, other accessory devices, and combinations thereof.

The apparatus of the invention may further comprise a power source connected to the rollers which when powered provide a motive force to the flexible material of the enclosed ring. The power source may be an external power source or an internal power source and may be transmitted through the shaft by various means.

In its various embodiments, the apparatus of the invention may further comprise an accessory tube. The accessory tube has at least one pathway through which accessory devices can be inserted into the patient or connected to external supporting devices.

The apparatus of the invention may be utilized to perform medical or non-medical procedures. In an embodiment of a procedure according to the invention, the apparatus is utilized for medical procedures. The procedure of this embodiment comprising the steps of: introducing a self-propellable, endoscopic apparatus according to the invention into the

rectum and anal canal of a patient, the apparatus being equipped with at least one accessory device and connected to at least one external support device; powering the apparatus to propel the apparatus forward through the anal canal and into the colon up to a location in the colon at which at least one medical procedure is to be performed; performing the at least one medical procedure with the at least one accessory device; optionally, serially propelling the apparatus to another location in the colon at which the at least one medical procedure is to be performed and performing said at least one medical procedure; propelling the apparatus backward through the colon and into the anal canal; and removing the apparatus from the patient.

In another embodiment of the invention, an endoscopic procedure is provided. The endoscopic procedure comprises the steps of: introducing a self-propellable, endoscopic apparatus into the generally tubular space or environment, the apparatus being equipped with at least one accessory device and connected to at least one external support device; powering the apparatus to propel and navigate the apparatus forward in the tubular space to a location at which at least one endoscopic procedure is to be performed; performing the at least one endoscopic procedure with the at least one accessory device; optionally, serially propelling the apparatus to another location in the tubular space at which the at least one endoscopic procedure is to be performed and performing said at least one endoscopic procedure; propelling the apparatus backward through tubular space; and removing the apparatus from the tubular space.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a sectional view of an apparatus in accordance with an exemplary embodiment of the invention.

Figure 2 is a sectional view of an apparatus in accordance with an additional exemplary embodiment of the invention.

Figure 3 is an axial cross-sectional view of an apparatus in accordance with an exemplary embodiment of the present invention.

Figure 4 is an axial cross-sectional view of an apparatus in accordance with an additional exemplary embodiment of the present invention.

Figure 5 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an exemplary embodiment of the invention.

Figure 6 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an exemplary embodiment of the invention.

Figure 7 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an additional exemplary embodiment of the invention.

Figure 8 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an exemplary embodiment of the invention.

Figure 9 is an enlarged, partial cross-sectional view of an apparatus in accordance with an additional exemplary embodiment of the invention.

Figure 10 is an additional enlarged, partial cross-sectional view of the apparatus shown in the previous figure.

Figure 11 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an exemplary embodiment of the invention.

Figure 12 is an additional enlarged, partial cross-sectional view of the apparatus shown in the previous figure.

Figure 13 is an enlarged, partial cross-sectional view of an apparatus in accordance with an additional exemplary embodiment of the present invention.

Figure 14 is a cross-sectional view of a bladder in accordance with an exemplary embodiment of the present invention.

Figure 15 is an additional cross-sectional view of bladder shown in the previous figure.

DETAILED DESCRIPTION OF THE INVENTION

The self-propellable or self-propelled endoscopic system or apparatus of the invention can be utilized to transport a variety of accessory devices to desired locations within a number of generally tubular spaces and environments, both collapsible and non-collapsible, for medical, industrial and commercial applications. With the system of the invention, an operator, such as a doctor, medical or other technician, can navigate and traverse within generally tubular spaces and/or environments whether of standard or non-standard dimensions and/or of uniform or non-uniform quality that cause difficulty when navigated by pushing a rod or "snake" through it. Examples of such spaces or environments would include, but are not limited to a circular, square, rectangular, or other shaped tube or a tube presenting one or more such shapes along its length that is partially occluded or interior surface of which is irregular, possibly due to material buildup on the surface. And may further include a route with varying diameters, constrictions and curves.

Figure 1 is a sectional view of an apparatus 100 in accordance with an exemplary embodiment of the invention. With reference to Figure 1 it will be appreciated that the system or apparatus 100 of the invention employs a toroid 102. In the embodiment of figure 1, the toroid 102 comprises a bladder 104 of a flexible material 106. The flexible material 106 of bladder 104 has an interior surface 120 and an exterior surface 122. Interior surface 120 of flexible material 106 defines an interior volume 124 of bladder 104. In some embodiments of the present invention, interior volume 124 of bladder 104 contains or is filled with a fluid, a gas, liquid or combination thereof. Exterior surface 122 of flexible material 106 defines a central cavity 126.

The apparatus 100 shown in figure 1 also includes a frame 108. Frame 108 both supports and interacts with flexible material 106 of bladder 104. Frame 108 is formed of a support structure 128 and a housing structure 130. With reference to figure 1, it will be appreciated that housing structure 130 is disposed in central cavity 126 defined by exterior surface 122 of flexible material 106 of bladder 104. Also with reference to figure 1, it will be appreciated that support structure 128 is disposed within interior volume 124 defined by interior surface 120 of flexible material 106 of bladder 104.

Support structure 128 and housing structure 130 each rotatably support a plurality of rollers. In figure 1, a pair of motive rollers 134 are shown contacting flexible material 106 of bladder 104. In the embodiment of figure 1, rotation of motive rollers 134 will cause flexible material 106 to move relative to the rotational axis of each motive roller 134. In the embodiment of figure 1, each motive roller 134 comprises a plurality of teeth 140. With reference to figure 1, it will be appreciated that the teeth 140 of each motive roller 134 mate with a first thread 142 of a worm gear 144. Accordingly, in the embodiment of figure 1, rotation of worm gear 144 will cause motive rollers 134 to rotate.

The power for rotating motive rollers 134 can be any of a variety of internal or external power sources known to those skilled in the art to be suitable for the given application. In the case of electrical power, the power source may be stored inside the apparatus, or the power may be transmitted via wires from outside the patient or space through an accessory tube (not shown) connected to the apparatus or to one or more electrical motors located inside the housing structure or otherwise operatively connected to motive rollers 134 and/or worm gear 144. The electrical motors, in turn, power the motive rollers 134 and/or worm gear 144. In the case of mechanical power, rollers 134 and/or worm gear 144 may be powered by a thin, flexible, spinning rod or wire powered from a remote motor

located outside the patient or space. The motion of the rod or wire is transmitted to the rollers located on the housing structure. Mechanical power may also be transmitted by a spinning spiral or spring component located inside or outside of the apparatus. This power may be manually generated.

In the embodiment of figure 1, housing structure 130 rotatably supports a plurality of stabilizing rollers 136. With reference to figure 1, it will be appreciated that each stabilizing roller 136 contacts exterior surface 122 of flexible material 106 of bladder 104. In the embodiment of figure 1, a suspended stabilizing roller 138 is located proximate each stabilizing roller 136. Each suspended stabilizing roller 138 contacts interior surface 120 of flexible material 106 of bladder 104. In the embodiment of figure 1, each suspended stabilizing roller 138 defines a groove 146 that is dimensioned to receive a portion of flexible material 106 and a portion of a stabilizing roller 136.

In the embodiment of figure 1, each suspended stabilizing roller 138 is pivotally coupled to an arm 148. In some useful embodiments of the present invention, each arm 148 and suspended stabilizing roller 138 act to bias exterior surface 122 of flexible material 106 against a stabilizing roller 136. Also in figure 1, a plurality of suspended motive rollers 132 are disposed proximate each motive roller 134. Each suspended motive roller 132 is pivotally supported by support structure 128. In some useful embodiments of the present invention, support structure 128 and suspended motive rollers 132 act to bias exterior surface 122 of flexible material 106 against motive rollers 134.

For some applications, bladder 104 may be generally longer than it is wide. However, for other applications or depending upon the size or dimension of the space or environment into which the toroid 102 is to be introduced, the bladder 104 may be of substantially equal length and width or may be wider than it is long.

Figure 2 is a sectional view of an apparatus 200 in accordance with an additional exemplary embodiment of the invention. With reference to Figure 2 it will be appreciated that apparatus 200 comprises a bladder 204 that is generally toroidal or ring shaped. Bladder 204 comprises a flexible material 206. Flexible material 206 of bladder 204 has an interior surface 220 and an exterior surface 222. Interior surface 220 of flexible material 206 defines an interior volume 224 of bladder 204. In some embodiments of the present invention, interior volume 224 of bladder 204 contains or is filled with a fluid, a gas, liquid or combination thereof. Exterior surface 222 of flexible material 206 defines a central cavity 226.

The apparatus 200 shown in figure 2 also includes a frame 208. Frame 208 both supports and interacts with the flexible material 206 of the bladder 204. Frame 208 comprises a support structure 228 and a housing structure 230. With reference to figure 2, it will be appreciated that housing structure 230 is disposed in central cavity 226 defined by exterior surface 222 of flexible material 206 of bladder 204. Also with reference to figure 2, it will be appreciated that support structure 228 is disposed within interior volume 224 defined by interior surface 220 of flexible material 206 of bladder 204.

Support structure 228 and housing structure 230 each rotatably support a plurality of rollers. In figure 2, a plurality motive rollers 234 are shown contacting flexible material 206 of bladder 204. In the embodiment of figure 2, rotation of motive rollers 234 is capable of causing flexible material 206 to move relative to the rotational axis of each motive roller 234. In the embodiment of figure 2, each motive roller 234 comprises a plurality of teeth 240. Each motive roller 234 is capable of mating with a worm gear 244.

With reference to figure 2, it will be appreciated that worm gear 244 comprises a first thread 242 and a second thread 243. In figure 2, the teeth 240 of a first set of motive roller 234 are shown mating with first thread 242 of worm gear 244. Accordingly, in the embodiment of figure 2, rotation of worm gear 244 will cause the first set of motive rollers 234 to rotate.

In some embodiments of an apparatus in accordance with an exemplary embodiment of the present invention, a one or more motive rollers are powered by a worm gear. A housing structure of the apparatus may contain a hollow cavity to hold the worm gear in place as illustrated, for example, in Figure 2. This hollow cavity allows the worm gear 244 to rotate relative to housing structure 230. Worm gear 244 may also move forwards and backward along the central axis of the apparatus in the embodiment of figure 2. This movement allows second thread 243 of worm gear 244 to selectively engage a second set of motive rollers while first thread 242 disengages from first set of motive rollers 234. This selective engagement may facilitate forwards and backwards movement of the apparatus. In a variation of this embodiment, the apparatus may be configured so that the first and the second set of motive rollers 234 respectively engage first and second threads 242, 243.

In the embodiment of figure 2, housing structure 230 rotatably supports a plurality of stabilizing rollers 236. With reference to figure 2, it will be appreciated that each stabilizing roller 236 contacts the exterior surface 222 of flexible material 206 of bladder 204. In the embodiment of figure 2, a plurality of suspended stabilizing rollers 238 are located proximate

each stabilizing roller 236. Each suspended stabilizing roller 238 contacts interior surface 220 of flexible material 206 of bladder 204. In some useful embodiments of the present invention, each suspended stabilizing roller 238 acts to bias exterior surface 222 of flexible material 206 against a stabilizing roller 236.

With continuing reference to figure 2, a suspended motive roller 232 is disposed proximate each motive roller 234. Each suspended motive roller 232 is pivotally supported by support structure 228. In some useful embodiments of the present invention, support structure 228 and suspended motive rollers 232 act to bias exterior surface 222 of flexible material 206 against motive rollers 234.

Various embodiments of housing structure 230 and support structure 228 are possible without deviating from the spirit and scope of the present invention. One exemplary embodiment may be viewed as two tubes positioned with one inside the other. The outer tube being the support structure which is located within the interior volume of the enclosed ring or bladder. The inner tube being the housing structure which is located within the central cavity. In another embodiment exemplary embodiment, either the support structure, the housing structure or both may be comprised of a series of one or more beams that may or may not form the general shape of a cylinder.

The housing and support structures may be, for example, cylindrical with a circular cross section or they may have a cross section in the shape of a square, rectangle, triangle, hexagon or any other shape with straight or curved surfaces or any combination thereof. The frame structures may also be comprised of multiple cross sectional shapes throughout its length. The flexible material 206 of the bladder 204 surface runs between the two tubes which are spaced in fixed relationship relative to each other. The distance between the two tubes is sufficient to accommodate the interlocking rollers or skids and to allow the flexible material 206 for bladder 204 to pass between the support and housing structures even if the material folds over itself or is bunched up.

Figure 3 is an axial cross-sectional view of an apparatus 300 in accordance with an exemplary embodiment of the present invention. Apparatus 300 includes a bladder 304 comprising a flexible material 306. The flexible material 306 of bladder 304 has an interior surface 320 and an exterior surface 322. Interior surface 320 of flexible material 306 defines an interior volume 324 of bladder 304. In some embodiments of the present invention, interior volume 324 of bladder 304 contains or is filled with a fluid, a gas, liquid or

combination thereof. Exterior surface 322 of flexible material 306 defines a central cavity 326.

In the embodiment of figure 3, a housing structure 330 is disposed in central cavity 326 defined by exterior surface 322 of flexible material 306 of bladder 304. The housing structure 330 rotatably supports a plurality of motive rollers 334. In figure 3, motive rollers 334 are shown contacting exterior surface 322 of flexible material 306. In the embodiment of figure 3, each motive roller 334 comprises a plurality of teeth 340. The teeth 340 of each motive roller 334 mate with a thread 342 of a worm gear 344. Thus, in the embodiment of figure 3, rotation of worm gear 344 will cause motive rollers 334 to rotate. Also in the embodiment of figure 3, rotation of the motive rollers 334 will cause flexible material 306 to move relative to the rotational axis of each motive roller 334.

With continuing reference to figure 3, it will be appreciated that a support structure 328 is disposed within an interior volume 324 defined by the interior surface 320 of flexible material 306. In the embodiment of figure 3, support structure 328 rotatably supports a plurality of suspended motive rollers 332. In figure 3, one suspended motive roller 332 is shown disposed proximate each motive roller 334. Also in figure 3, each suspended motive roller 332 can be seen contacting interior surface 320 of flexible material 306 of bladder 304. In some useful embodiments of the present invention, support structure 328 and suspended motive rollers 332 act to bias exterior surface 322 of flexible material 306 against motive rollers 334.

In the exemplary embodiment of figure 3, housing structure 330 and support structure 328 each have a generally tubular shape. Thus, housing structure 330 and support structure 328 may be viewed as two tubes positioned with one inside the other. The outer tube being support structure 328 which is located within interior volume 324 defined by interior surface 320 of bladder 304. The inner tube being housing structure 330 which is located within central cavity 326 defined by exterior surface 322 of bladder 304.

It will be appreciated that various embodiments of housing structure 330 and support structure 328 are possible without deviating from the spirit and scope of the present invention. The housing and support structures may be, for example, cylindrical with a circular cross section or they may have a cross section in the shape of a square, rectangle, triangle, hexagon or any other shape with straight or curved surfaces or any combination thereof. The frame structures may also be comprised of multiple cross sectional shapes throughout their length. The flexible material 306 of the bladder 304 surface runs between

the two structures which are spaced in fixed relationship relative to each other. The distance between the two structures is sufficient to accommodate the interlocking rollers or skids and to allow the flexible material 306 for bladder 304 to pass between the support and housing structures even if the material folds over itself or is bunched up.

Figure 4 is an axial cross-sectional view of an apparatus 400 in accordance with an additional exemplary embodiment of the present invention. Apparatus 400 comprises a bladder 404 of a flexible material 406. In figure 4 a support structure 428 is shown disposed within an interior volume 424 defined by the interior surface 420 of flexible material 406. In the embodiment of figure 4, support structure 428 rotatably supports a plurality of suspended stabilizing rollers 438. With reference to figure 4, it will be appreciated that each suspended stabilizing roller 438 contacts the interior surface 420 of flexible material 406 of bladder 404. In some useful embodiments of the present invention, support structure 428 and suspended stabilizing roller 438 act to bias exterior surface 422 of flexible material 406 against a stabilizing roller 436.

In the embodiment of figure 4, a housing structure 430 is disposed in a central cavity 426 defined by an exterior surface 422 of flexible material 406 of bladder 404. Housing structure 430 rotatably supports a plurality of stabilizing rollers 436. With reference to figure 4, it will be appreciated that each stabilizing roller 436 contacts the interior surface 420 of flexible material 406 of bladder 404. In the embodiment of figure 4, each suspended stabilizing roller 438 defines a groove 446 that is dimensioned to receive a portion of flexible material 406 and a portion of a stabilizing roller 436.

Figure 5 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an exemplary embodiment of the invention. Apparatus 500 comprises a housing structure 530 and a support structure 528. Housing structure 530 rotatably supports a motive roller 534 and support structure 528 rotatably supports a plurality of suspended motive rollers 532. A flexible material 506 is disposed between motive roller 534 and suspended motive rollers 532. Flexible material 506 may form, for example, a portion of a bladder in accordance with the present invention. Suspended motive rollers 532 are rotatably supported by a support structure 528. In the embodiment of figure 5, housing structure 530 rotatably supports a worm gear 544. A first thread 542 of worm gear 544 engages teeth 540 of motive roller 534. In the embodiment of figure 5, rotation of worm gear 544 will cause motive roller 534 to rotate. Rotation of motive roller 534, in turn, causes flexible material 506 to move

relative to housing structure 530. With reference to figure 5, it will be appreciated that flexible material 506 has an interior surface 520 and an exterior surface 522.

Figure 6 is an enlarged, partial, cross-sectional view of an apparatus 600 in accordance with an exemplary embodiment of the invention. Apparatus 600 comprises a housing structure 630 that rotatably supports a worm gear 644. A first thread 642 of worm gear 644 engages the teeth 640 of a motive roller 634. Motive roller 634 is rotatably supported by housing structure 630. A flexible material 606 is disposed between motive roller 634 and a skid 650. Flexible material 606 may form, for example, a portion of a bladder in accordance with the present invention.

In the embodiment of figure 6, rotation of worm gear 644 causes rotation of motive roller 634. Rotation of motive roller 634, in turn, causes flexible material 606 to move relative to housing structure 630. With reference to figure 6, it will be appreciated that skid 650 contacts an interior surface 620 of flexible material 606. In some useful embodiments of the present invention, skid 650 acts to bias an exterior surface 622 of flexible material 606 against motive roller 634.

Figure 7 is an enlarged, partial, cross-sectional view of an apparatus 603 in accordance with an additional exemplary embodiment of the invention. Apparatus 603 comprises a housing structure 630 that rotatably supports a motive roller 634. A flexible material 606 is disposed between motive roller 634 and a skid 650. In the embodiment of figure 7, a pair of springs 652 act to bias skid 650 against an interior surface 620 of flexible material 606. Springs 652 are diagrammatically illustrated in figure 7. Springs 652 may comprise, for example, sheet metal arms. A compression motion and an extension motion of springs 652 and skid 650 are illustrated with arrows in figure 7.

In some useful embodiments of the present invention, skid 650 and springs 652 act to bias an exterior surface 622 of flexible material 606 against motive roller 634. Teeth 640 of motive roller 634 engage a first thread 642 of a worm gear 644 that is rotatably supported by housing structure 630. In the embodiment of figure 7, rotation of worm gear 644 causes rotation of motive roller 634. Rotation of motive roller 634, in turn, causes flexible material 606 to move relative to housing structure 630.

Figure 8 is an enlarged, partial, cross-sectional view of an apparatus in accordance with an exemplary embodiment of the invention. Apparatus 700 includes a frame 708 comprising a housing structure 730 and a support structure 728. Housing structure 730

rotatably supports a motive roller 734 and support structure 728 rotatably supports a plurality of suspended motive rollers 732. A flexible material 706 is disposed between motive roller 734 and suspended motive rollers 732.

Suspended motive rollers 732 are rotatably supported by a support structure 728. A pair of springs 752 of support structure 728 are diagrammatically illustrated in figure 8. In the embodiment of figure 8, springs 752 act to bias suspended motive rollers 732 against an interior surface 720 of flexible material 706. Springs 752 may comprise, for example, sheet metal arms. A compression motion and an extension motion of springs 752 and suspended motive rollers 732 are illustrated with arrows in figure 8.

In the embodiment of figure 8, housing structure 730 rotatably supports a worm gear 744. A first thread 742 of worm gear 744 engages teeth 740 of motive roller 734. In the embodiment of figure 8, rotation of worm gear 744 will cause motive roller 734 to rotate. Rotation of motive roller 734, in turn, causes flexible material 706 to move relative to housing structure 730.

Figure 9 is an enlarged, partial cross-sectional view of an apparatus 800 in accordance with an additional exemplary embodiment of the invention. With reference to Figure 9 it will be appreciated that apparatus 800 comprises a bladder 804. In some embodiments of the present invention, bladder has a generally toroidal or ring shape. Bladder 804 comprises a flexible material 806. Flexible material 806 of bladder 804 has an interior surface 820 and an exterior surface 822. Interior surface 820 of flexible material 806 defines an interior volume 824 of bladder 804. In some embodiments of the present invention, interior volume 824 of bladder 804 contains or is filled with a fluid, a gas, liquid or combination thereof. Exterior surface 822 of flexible material 806 defines a central cavity 826.

The apparatus 800 shown in figure 9 also includes a frame 808. Frame 808 both supports and interacts with the flexible material 806 of the bladder 804. Frame 808 comprises a support structure 828 and a housing structure 830. In the embodiment of figure 9, housing structure 830 rotatably supports a stabilizing roller 836 and support structure rotatably supports a suspended stabilizing roller 838. With reference to figure 9, it will be appreciated that suspended stabilizing roller 838 contacts the interior surface 820 of flexible material 806 of bladder 804. Stabilizing roller 836 is shown contacting an exterior surface 822 of flexible material 806 of bladder 804. The rotation of the rollers and the movement of flexible material 806 are illustrated with arrows in figure 9.

Figure 10 is an additional enlarged, partial cross-sectional view of apparatus 800 shown in the previous figure. In some useful embodiments of the present invention, suspended stabilizing roller 838 acts to bias exterior surface 822 of flexible material 806 against stabilizing roller 836. In the embodiment of figure 10, an arm 848 of support structure 828 acts to bias suspended stabilizing roller 838 against interior surface 820 of flexible material 806. A flexing motion of arm 848 is illustrated using arrows in figure 10.

Figure 11 is an enlarged, partial, cross-sectional view of an apparatus 900 in accordance with an exemplary embodiment of the invention. Apparatus 900 comprises a housing structure 930 that rotatably supports a worm gear 944. A stabilizing roller 936 is rotatably supported by housing structure 930. A flexible material 906 is disposed between stabilizing roller 936 and a skid 950. Flexible material 906 may form, for example, a portion of a bladder in accordance with the present invention. With reference to figure 11, it will be appreciated that skid 950 contacts an interior surface 920 of flexible material 906. In some useful embodiments of the present invention, skid 950 acts to bias an exterior surface 922 of flexible material 906 against stabilizing roller 936.

Figure 12 is an additional enlarged, partial cross-sectional view of apparatus 900 shown in the previous figure. Skid 950 of apparatus 900 is shown in cross section in figure 12. With reference to figure 12, it will be appreciated that skid 950 defines a depression 956. In the embodiment of figure 12, depression 956 is dimensioned to receive a portion of flexible material 906 and a portion of stabilizing roller 936. The rotation of stabilizing roller 936 and the motion of flexible material 906 are illustrated with arrows in figure 12.

Figure 13 is an enlarged, partial cross-sectional view of apparatus 900 in accordance with an additional exemplary embodiment of the present invention. Apparatus 900 includes a frame 908 comprising a housing structure 930 and a support structure 928. A stabilizing roller 936 is rotatably supported by housing structure 930. A flexible material 906 is disposed between stabilizing roller 936 and a skid 950. With reference to figure 13, it will be appreciated that skid 950 contacts an interior surface 920 of flexible material 906. In some useful embodiments of the present invention, skid 950 acts to bias exterior surface 922 of flexible material 906 against stabilizing roller 936. In the embodiment of figure 13, an arm 948 of support structure 928 acts to bias skid 950 against interior surface of flexible material 906. A flexing motion of arm 948 is illustrated using an arrow in figure 13.

Figure 14 is a cross-sectional view of a bladder 104 in accordance with an exemplary embodiment of the present invention. Bladder 104 comprises a flexible material 106. The

movement of flexible material 106 is illustrated with arrows in figure 14. With reference to Figure 14, an exterior portion of bladder 104 can be viewed as moving in one direction while an interior portion of bladder 104 is moving in the opposite direction. The result is that the entire shape can move along its central axis while the external material rolls around itself. Thus, the flexible material may be described as circulating around and through the frame in a continuous motion from inside the central cavity long is central axis to the outside where the exterior surface of the flexible material travels along in contact with the interior surface of a generally tubular space or environment or other lumen. A travel direction of bladder 104 is labeled TD in figure 14. This motion is well adapted to travel within a generally cylindrical or tubular space, even a collapsible one, such as exists with the colon or rectal canal. The entire object moves with minimal to no slipping because its exterior surface remains in relatively constant or continuous contact with the interior of the space while the interior surface of the flexible materials moves forward in the direction of travel as shown.

Figure 15 is an additional cross-sectional view of bladder 104 shown in the previous figure. In the embodiment of figure 15, bladder 104 is traveling a in second travel direction TD that is generally opposite the travel direction shown in the previous figure. The movement of flexible material 106 of bladder 104 is illustrated with arrows in figure 15. With reference to Figure 15, an exterior portion of bladder 104 can be viewed as moving in one direction while an interior portion of bladder 104 is moving in the opposite direction.

In some exemplary embodiments of an apparatus in accordance with the present invention, a frame is formed of a support structure and a series of at least two sets of interlocking rollers or skids located on the support structure. The support structure is located within the interior volume of the enclosed ring. The rollers or skids are located so as to maintain the flexible material of the enclosed ring between them. To further accommodate folds and wrinkles in the flexible material the rollers or skids may be suspended and may apply force to the flexible material and the matching rollers or skids. Embodiments of possible suspension mechanisms are illustrated in the figures.

The ends of support and housing structures may be tapered for some applications. Embodiments of the invention having tapered ends are well-suited, but not necessary for medical applications and procedures, e.g., colonoscopy or rectal examination. However, such tapering is not necessary for all applications, particularly those involving spaces or environments of large dimension. The tapered ends of the support and housing structures may serve a number of functions, including, but not limited to allowing the two structures to

fit and work together without sliding apart; presenting a smooth and gradual surface to over which the flexible material travels, and easing the apparatus' through constrictions and its passage around curves and corners.

The series of at least two sets of interlocking rollers or skids are located on the support and housing structures or in the case where only a support structure is utilized, the rollers or skids are located on the support structure. A set of rollers or skids may be comprised of one or more roller, one or more skid or combination thereof located on one or more of the structures. A set may be formed of a single roller or skid, a pair of adjacent rollers or skid, a single roller or skid on one structure and a pair comprised of two or more rollers, two or more skids or a combination of both on the other, and other variations and combinations of rollers and skids located in corresponding aligned position on each structure. The rollers or skids are interlocked in two directions, along and across the apparatus' central axis. The interlocking is done in such a way as to maintain a generally constant or fixed distance between the support and housing structures, so that they are in a generally fixed spatial relationship. As shown in the figures, the flexible material of the enclosed ring passes between the rollers or skids. This helps to prevent the toroid's flexible material from being compressed between the two structures except where it interacts with the rollers or skids. When powered, the rollers engage the flexible material and provide a motive, directional force to the flexible material which allows the apparatus to move in a forward or backward direction. With the exterior surface of the enclosed ring contacting and conforming to the interior surface or surfaces of a generally tubular space or environment, the powering of the rollers moves the flexible material as illustrated in the figures. This movement of the flexible material provides the self-propulsion for the apparatus.

If unpowered, the rollers or skids provide a means of facilitating the motion of the flexible material between the support and housing structures, for example when the apparatus is initially being introduced. When propelled, preferably, only the rollers on the advancing side of the apparatus are powered. This will tend to keep the flexible material from wrinkling, kinking and bunching-up by pulling the flexible material through the toroid's central cavity instead of pushing it. However, the apparatus can be operated with the rearward roller (rearward relative the direction of motion) being powered or both forward and rearward rollers being powered.

The fluid-filled toroid is also well adapted to the numerous curves, corners and constrictions found in body cavities and lumens. As one part of the shape is squeezed or pushed the liquid or gas is displaced and accommodated by the flexibility of the bladder.

The apparatus may include an accessory tube, such as a flexible tube, connected to the apparatus and leading outside the patient or other space into which it is introduced. For example, as the apparatus enters and travels within the patient, the tube remains connected and is pulled by the device. It can also be pushed or pulled as a means of moving the inside a patient or other space. The accessory tube can be a single pathway or conduit or may contain multiple pathways or conduits which can be used to insert a variety of accessory devices into the patient or to connect such devices to external support devices know to those skilled in the art, including but not limited to computers, analytical or diagnostic equipment or other electronic equipment appropriate to the given application.

Various types of accessory devices can be utilized with or mounted to the apparatus. Such accessory devices include, but are not limited to, endoscopes, cameras, fiber optic cables, electronic communication cables, lasers, surgical instruments, medical instruments, diagnostic instruments, instrumentation, sensors, stent catheters, fluid delivery devices, drug delivery devices, electronic devices, tools, sampling devices, assay devices, other accessory devices, and combinations thereof.

The material requirements for the various components of the invention can be fulfilled by a number of substances. For medical applications, all materials must possess a high degree of biocompatibility and be capable of withstanding sterilization methods know to those skilled in the art, such as radiation, steam or chemical vapor.

The fluid located inside the enclosed ring or bladder may be a liquid, such as a light oil, water, saline solution, lubricant; a gas, such as air, nitrogen, or carbon dioxide; or a combination thereof. Preferably, for medical or veterinary application or use, the fluid will be non-toxic. For the enclosed ring or bladder the flexible material should be a material with puncture, rupture and abrasion resistance characteristic as appropriate to the conditions of the interior surface of the space or environment into which the apparatus will be introduced. The flexible material may also posses a textured surface that would assist its motion against the surface of the lumen it traverses. Other characteristics to be considered in the selection of suitable materials, for example, softness, flexibility and conformability. The toroid's material must also be capable of being sealed into an enclosed ring or closed bladder by some

means such as heat sealing, an adhesive or a chemical bond. A variety of polymeric or plastic materials can be used as the flexible material.

The support and housing structures may be formed of either a semi-flexible or semi-rigid material such as a polymer or a rigid material, such as stainless steel, a composite material or combinations thereof. The rollers or skids will require a material or group of materials that is high in strength and capable of being formed into very small parts. The roller material must also provide a sufficiently high degree of friction (not slip) against the flexible material without damaging it while the skids must provide a sufficiently low degree of friction (slip) against the flexible material without damaging it. The surfaces of the support and housing structures may be comprised of one or more materials that reduce or eliminate friction caused by the motion of the flexible material across the surfaces of the support and housing structures.

For applications of a non-medical nature, the materials required must retain most properties described above but do not necessarily require biocompatibility or sterilization tolerance. The materials used for the invention in non-medical applications will require sufficient durability and compatibility to suit the environment in which they are to be used.

Though a number of applications and uses of the apparatus of the invention have been identified herein above, additional applications and uses include, but are not limited to, inspection of difficult to reach pipes, tubes and caverns by carrying a camera or other optical, electrical or mechanical inspection device; transporting remotely controlled tools for use in difficult to reach locations; routing or pulling cable, wires, rope, etc. through long narrow passages; pushing or pulling material through a pipe by taking advantage of the invention's ability to conform to the shape of its environment allowing it to provide a seal between the spaces on either side, i.e. the invention could facilitate emptying a pipe of material without mixing it with air or other material on the other side of the invention. Many of these applications would work equally well if the device was self-propelled or simply pushed or pulled from the outside.

While exemplary embodiments of this invention and methods of practicing the same have been illustrated and described, it should be understood that various changes, adaptations, and modifications might be made therein without departing from the spirit of the invention and the scope of the appended claims.

CLAIMS

1. A propulsion apparatus for transport of accessory devices within body cavities or canals, sections of pipe, lumens, and other generally tubular spaces and environments, comprising:

a toroid, the toroid being a fluid-filled, enclosed ring formed of a flexible material, the enclosed ring defining a central cavity, having an interior volume and presenting an exterior surface and an interior surface which move continuously in opposite directions when the apparatus is in motion;

a frame formed of a support structure located within the interior volume of the enclosed ring, a housing structure concentrically and coaxially located relative to the support structure and disposed in the central cavity of the enclosed ring; and

a series of at least two sets of interlocking rollers or skids located on the support and housing structures, the rollers or skids being located so as to maintain the two structures in a fixed spatial relationship with the flexible material of the enclosed ring being positioned between the two structures and the rollers or skids located thereon.

2. The apparatus of claim 1, further comprising at least one accessory device.

3. The apparatus of claim 1, further comprising a power source connected to the rollers which when powered provide a motive force to the flexible material of the enclosed ring.

4. The apparatus of claim 3, wherein the power source is an external power source.

5. The apparatus of claim 3, wherein the power source is an internal power source.

6. The apparatus of claim 1, wherein the flexible material is a polymeric material.

7. The apparatus of claim 1, further comprising a power source for powering the rollers, and at least one accessory device.

8. The apparatus of claim 1, further comprising an accessory tube, the tube having at least one pathway through which accessory devices can be inserted or connected to external supporting devices.

9. The apparatus of any one of claims 2, 7 or 8, wherein the at least one accessory device is selected from the group consisting of endoscopes, cameras, fiber optic cables, electronic communication cables, lasers, surgical instruments, medical instruments, diagnostic instruments, instrumentation, sensors, stent catheters, fluid delivery devices, drug delivery devices, electronic devices, tools, sampling devices, assay devices, other accessory devices, and combinations thereof.

10. The apparatus of claim 1, further comprising a worm gear.

11. The apparatus of claim 1, wherein at least one of the rollers is suspended by a spring.

12. The apparatus of claim 1, wherein at least one of the rollers is rotatably supported by an arm.

13. A propulsion apparatus for transport of accessory devices, comprising:

a toroid, the toroid being a fluid-filled, enclosed ring formed of a flexible material, the enclosed ring defining a central cavity, having an interior volume and presenting an exterior surface and an interior surface which move continuously in opposite directions when the apparatus is powered;

a frame formed of a support structure located within the interior volume of the enclosed ring, a housing structure concentrically and coaxially located relative to the support structure and disposed in the central cavity of the enclosed ring;

a series of at least two sets of interlocking rollers or skids located on the support and housing structures, the rollers or skids being located so as to maintain the two structures in a fixed spatial relationship with the flexible material of the enclosed ring being positioned between the two structures and the rollers or skids located thereon;

an accessory tube, the tube having at least one pathway through which accessory devices can be inserted or connected to external supporting devices;

at least one accessory device inserted through the accessory tube or connected through the accessory tube to at least one external supporting device; and

a power source connected to the rollers which when the apparatus is powered provide a motive, directional force to the flexible material.

14. A propulsion apparatus for transport of accessory devices, comprising:

a toroid, the toroid being a fluid-filled, enclosed ring formed of a flexible material, the enclosed ring defining a central cavity and having an interior volume;

a powered frame formed of a support structure located within the interior volume of the enclosed ring, a housing structure concentrically and coaxially located relative to the support structure and disposed within the central cavity of the enclosed ring, a series of at least two sets of interlocking rollers or skids located on the support and housing structures, the rollers or skids being located so as to maintain the two structures in a fixed spatial relationship with the flexible material of the enclosed ring being positioned between the two structures and the rollers or skids located thereon, the rollers being connected to a power source and when powered providing a motive, directional force to the flexible material.

15. An endoscopic, medical procedure; comprising the steps of:

introducing a self-propellable, endoscopic apparatus into the rectum and anal canal of a patient, the apparatus being equipped with at least one accessory device and connected to at least one external support device;

powering the apparatus to propel the apparatus forward through the anal canal and into the colon up to a location in the colon at which at least one medical procedure is to be performed;

performing the at least one medical procedure with the at least one accessory device;

optionally, serially propelling the apparatus to another location in the colon at which the at least one medical procedure is to be performed and performing said at least one medical procedure;

propelling the apparatus backward through the colon and into the anal canal; and

removing the apparatus from the patient.

16. An endoscopic, medical procedure; comprising the steps of:

introducing a self-propellable, endoscopic apparatus into the rectum and anal canal of a patient, the self-propellable endoscopic apparatus comprising:

a toroid, the toroid being a fluid-filled, enclosed ring formed of a flexible material, the enclosed ring defining a central cavity and having an interior volume; a powered frame formed of a support structure located within the interior volume of the enclosed ring, a housing structure concentrically and coaxially located relative to the support structure and disposed within the central cavity of the enclosed ring, a series of at least two sets of interlocking rollers or skids located on the support and housing structures, the rollers or skids being located so as to maintain the two structures in a fixed spatial relationship with the flexible material of the enclosed ring being positioned between the two structures and the rollers or skids located thereon, the rollers being connected to a power source and when powered providing a motive, directional force to the flexible material; and at least one accessory device and connected to at least one external support device;

powering the apparatus to propel the apparatus forward through the anal canal and into the colon up to a location in the colon at which at least one medical procedure is to be performed;

performing the at least one medical procedure with the at least one accessory device;

optionally, serially propelling the apparatus to another location in the colon at which the at least one medical procedure is to be performed and performing said at least one medical procedure;

propelling the apparatus backward through the colon and into the anal canal; and

removing the apparatus from the patient.

17. An endoscopic procedure; comprising the steps of:

introducing a self-propellable, endoscopic apparatus into the generally tubular space or environment, the apparatus being equipped with at least one accessory device and connected to at least one external support device;

powering the apparatus to propel and navigate the apparatus forward in the tubular space to a location at which at least one endoscopic procedure is to be performed;

performing the at least one endoscopic procedure with the at least one accessory device;

optionally, serially propelling the apparatus to another location in the tubular space at which the at least one endoscopic procedure is to be performed and performing said at least one endoscopic procedure;

propelling the apparatus backward through tubular space; and

removing the apparatus from the tubular space.