US 20100201187A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2010/0201187 A1

(43) Pub. Date: Aug. 12, 2010

Jacobsen

(54) VERSATILE ENDLESS TRACK FOR LIGHTWEIGHT MOBILE ROBOTS

(76) Inventor: Stephen C. Jacobsen, Salt Lake City, UT (US)

Correspondence Address:
THORPE, NORTH & WESTERN, LLP
P.O BOX 1219
SANDY, UT 84091-1219 (US)

(21) Appl. No.: 12/694,996

(22) Filed: Jan. 27, 2010

Related U.S. Application Data

(62) Division of application No. 11/985,346, filed on Nov. 13, 2007, now abandoned.

(60) Provisional application No. 60/858,804, filed on Nov. 13, 2006.

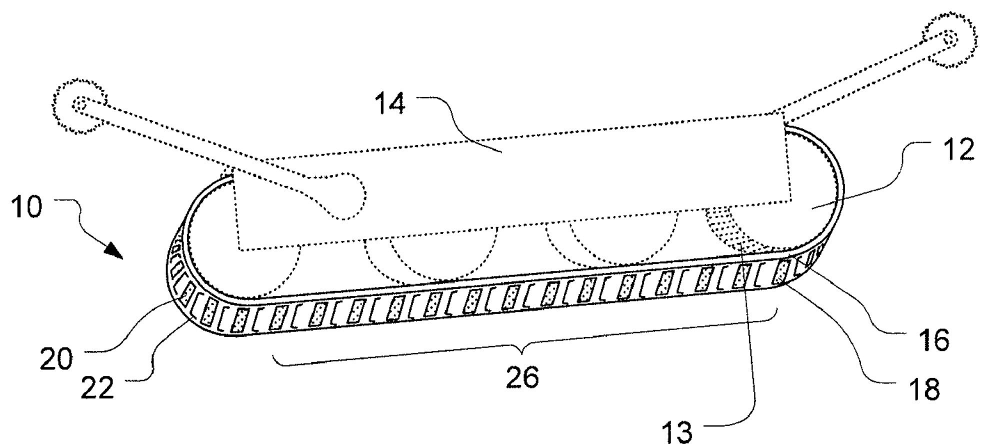
Publication Classification

(51) Int. Cl.
B62D 55/27 (2006.01)

(52) U.S. Cl. 305/185

(57) ABSTRACT

A versatile endless track system for a lightweight robotic vehicle is disclosed. The versatile endless track system includes a flexible track configured for mounting about a plurality of track supports of the lightweight robotic vehicle. A plurality of traction pads including at least two different types of traction pads are inserted into and supported by a plurality of receptacles contained within the flexible track. The different types of traction pads provide different ground-interfacing profiles designed to provide traction with respect to ground surfaces having different traction properties. Optionally, traction pads can be removable, allowing the versatile endless track to be reconfigured. A method of configuring a versatile endless track is also disclosed.



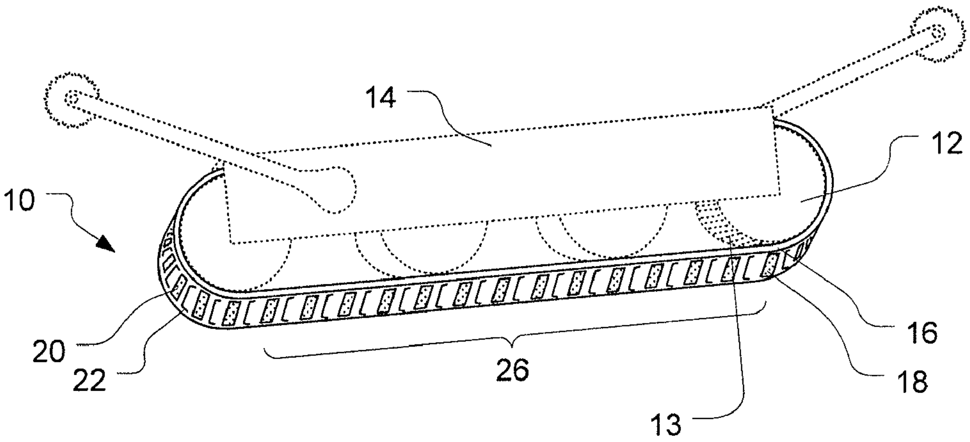


FIG. 1

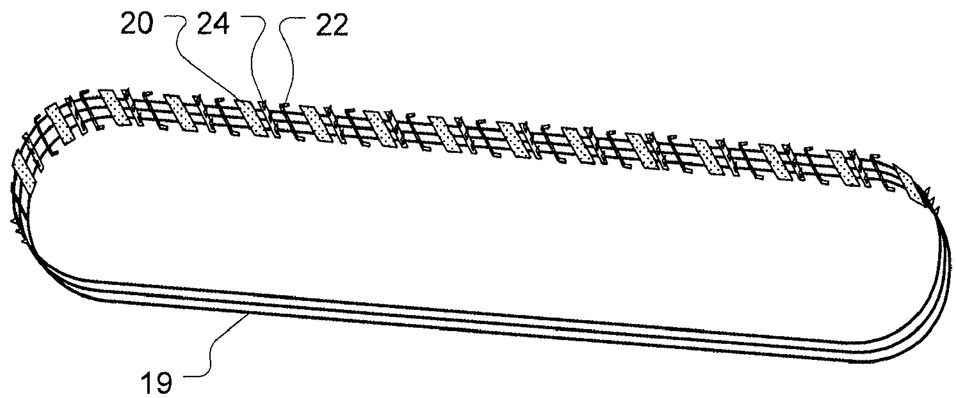


FIG. 2

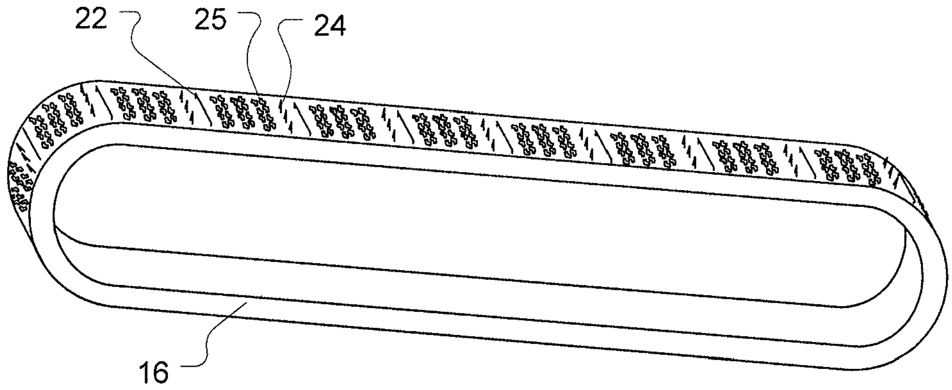


FIG. 3

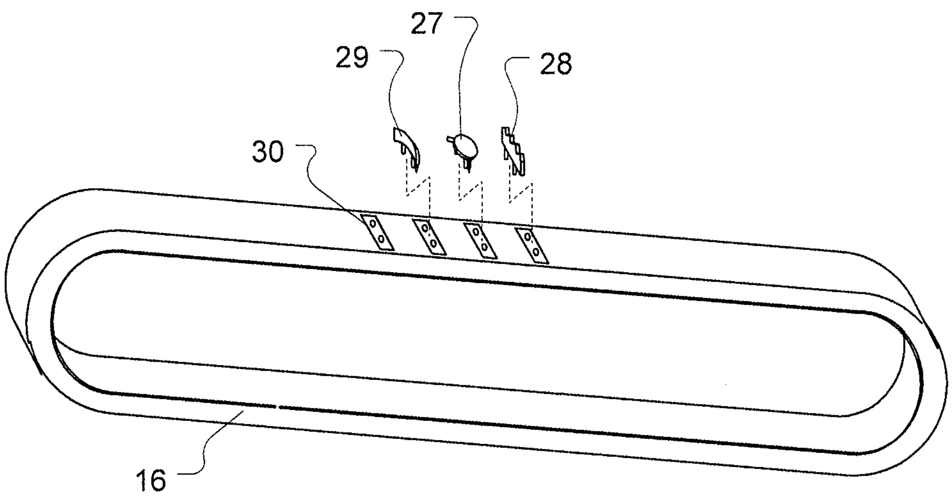


FIG. 4

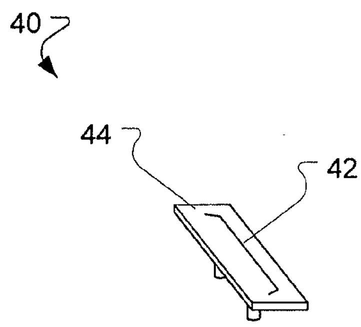


FIG. 5

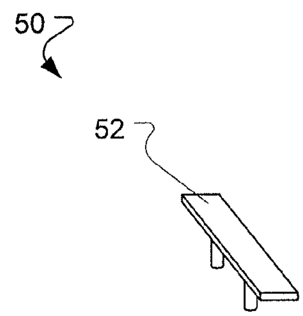


FIG. 6

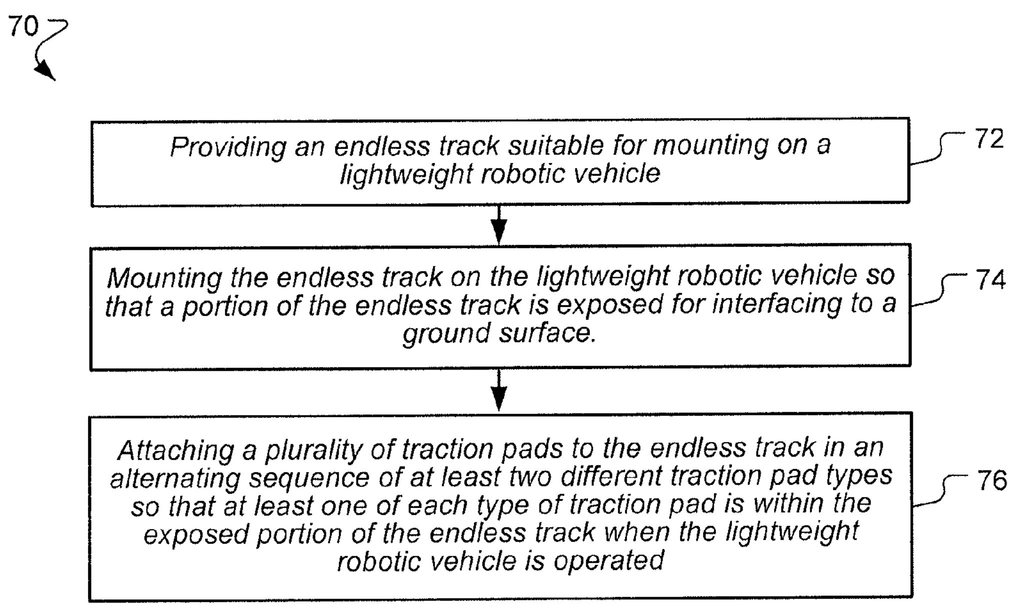


FIG. 7

VERSATILE ENDLESS TRACK FOR LIGHTWEIGHT MOBILE ROBOTS

RELATED APPLICATIONS

[0001] This application is a divisional of prior U.S. patent application Ser. No. 11/985,346, filed Nov. 13, 2007, and entitled "Versatile Endless Track for Lightweight Mobile Robots," which claims the benefit of U.S. Provisional Patent Application No. 60/858,804, filed Nov. 13, 2006 in the United States Patent and Trademark Office, and entitled, "Versatile Endless Track for Lightweight Mobile Robots," each of which is incorporated by reference in its entirety herein.

FIELD OF THE INVENTION

[0002] The present invention relates to small, unmanned ground robotic vehicles. More particularly, the present invention relates to a versatile endless track for a lightweight robotic vehicle.

BACKGROUND OF THE INVENTION AND RELATED ART

[0003] Unmanned robotic vehicles can be deployed in a variety of applications and environments, including for example, search and rescue, military operations, and industrial operations. Unmanned robotic vehicles can help to avoid the need to expose humans to hazardous environments, such as unstable buildings, military conflict situations, and chemically, biologically, or nuclear contaminated environments.

[0004] Unmanned robotic vehicles face many challenges when attempting mobility. Terrain can vary widely, including for example, bumpy or smooth surfaces, firm or soft ground, loose and shifting materials, etc. For small robotic vehicles, the challenges become even greater. A vehicle optimized for operation in one environment may perform poorly in other environments.

[0005] The use of endless tracks are known to provide a good compromise which allows a robotic vehicle to accommodate a large variation in terrain types while maintaining relatively good traction and maneuverability. For example, tank-like vehicles using a pair of parallel endless tracks can provide high stability in some environments.

[0006] For small robotic vehicles, however, the traction performance of endless tracks can be less than desired. In part, traction performance for small robotic vehicles can be poor because the robotic vehicle is relatively lightweight. Little downward force is applied to the endless track, resulting in reduced frictional forces between the endless track and the ground surface.

SUMMARY OF THE INVENTION

[0007] The present invention includes a versatile endless track system for a lightweight robotic vehicle that helps to overcome problems and deficiencies inherent in the prior art. In one embodiment, the versatile endless track system includes a flexible track on which a plurality of traction pads are disposed. At least two different traction pad types are included, where each type of traction pad has a different ground-interfacing profile designed to provide traction with respect to ground surfaces having different traction properties.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present invention will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings merely depict exemplary embodiments of the present invention, they are, therefore, not to be considered limiting of its scope. It will be readily appreciated that the components of the present invention, as generally described and illustrated in the figures herein, can be arranged and designed in a wide variety of different configurations. Nonetheless, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0009] FIG. **1** illustrates a perspective view of a versatile endless track mounted on a lightweight robotic vehicle according to an embodiment of the present invention;

[0010] FIG. **2** illustrates a perspective view of a versatile endless track in accordance with another embodiment of the present invention;

[0011] FIG. **3** illustrates a perspective view of a versatile endless track according to another embodiment of the present invention;

[0012] FIG. **4** illustrates a perspective view of a versatile endless track according to yet another embodiment of the present invention;

[0013] FIG. **5** illustrates a perspective view of one type of traction pad according to an embodiment of the present invention;

[0014] FIG. **6** illustrates a perspective view of another type of traction pad according to an embodiment of the present invention; and

[0015] FIG. **7** illustrates a flow diagram of a method for configuring an endless track with traction pads according to an embodiment of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0016] The following detailed description of exemplary embodiments of the invention makes reference to the accompanying drawings, which form a part hereof and in which are shown, by way of illustration, exemplary embodiments in which the invention may be practiced. While these exemplary embodiments are described in sufficient detail to enable those skilled in the art practice the invention, it should be understood that other embodiments may be realized and that various changes to the invention may be made without departing from the spirit and scope of the present invention. Thus, the following more detailed description of the embodiments of the present invention is not intended to limit the scope of the invention, as claimed, but is presented for purposes of illustration only and not limitation to describe the features and characteristics of the present invention, to set forth the best mode of operation of the invention, and to sufficiently enable one skilled in the art to practice the invention. Accordingly, the scope of the present invention is to be defined solely by the appended claims.

[0017] The following detailed description and exemplary embodiments of the invention will be best understood by reference to the accompanying drawings, wherein the elements and features of the invention are designated by numerals throughout.

[0018] In general, the environments faced by lightweight robotic vehicle can be highly variable, as lightweight robotic vehicles may be used indoors or outdoors, on land or water. The term "ground" is thus used broadly within the present application to refer generally to the surface on which the lightweight robotic vehicle is operating, which can include ground, vegetation, road surface, flooring, carpet, liquid surfaces, and the like. The highly variable environment encountered by lightweight robotic vehicles differs from that of traditional tracked vehicles, such as tanks or earth working equipment, which typically operate in very limited environments (e.g., outdoors on unprepared surfaces).

[0019] For example, earth working equipment often includes cleat bars on the tracks to help provide traction in soft or slippery conditions, such as mud or soft ground. The cleat bars sink into and engage with the ground, helping to reduce slippage of the tracks. Good performance is also obtained on hard ground, because the weight of the equipment is sufficiently large to develop large downward forces which translate into high friction (and thus traction) for portions of the track in contact with the ground.

[0020] In contrast, a lightweight robotic vehicle is less able to develop large downward force, and thus different approaches to developing traction are required. Although one approach is to use cleat profiles adapted for developing traction when lightly loaded, such a solution is likely to only perform well over a relatively narrow range of environmental conditions. For example, cleats might perform well when the robotic vehicle is operated over a very soft surface (e.g., sand or soil), but provide very little traction when operated over a very hard, smooth surface (e.g., glass or polished stone). Accordingly, a particular cleat or other traction device configuration is often a compromise solution that performs well over a relatively narrow range of surface conditions.

[0021] It has been recognized by the inventor of the present invention that a versatile endless track can provide traction over a wide range of conditions by including a number of different traction pads of different ground-interfacing profiles on the endless track. With reference to FIG. **1**, shown is an illustration of a versatile endless track, according to a first exemplary embodiment of the present invention. The versatile endless track, shown generally at **10**, is mounted on a lightweight robotic vehicle **14**, threaded about a plurality of track supports **12**. The track includes a flexible track **16**. Disposed along the flexible track **16** are a plurality of traction pads **18**. Different types **20**, **22** of traction pads are included, each traction pad type having a different exposed ground-interfacing profile designed to provide traction with respect to ground surfaces having different traction properties.

[0022] An exposed portion **26** of the flexible track **16** engages with the ground when the lightweight robotic vehicle is in operation. It will be appreciated that the exposed portion is constantly changing as the flexible track is rotated around the plurality of track supports. Sufficient traction pads **18** of each type **20**, **22** can be included so that at least one traction pad of each type is present on the exposed ground-engaging portion of the flexible track at all times.

[0023] The flexible track **16** can be constructed in various ways. For example, the flexible track can be a loop which is slid laterally over the track supports **12**. Alternately, the track can be a long assembly which is threaded through the track supports after which ends of the flexible track are attached together to form a loop. The flexible track can be an elastic belt, for example of rubber or other elastomeric material. As another example, the flexible track can be two or more cables **19** on which the traction pads are threaded as shown in FIG. **2** in accordance with another embodiment of the present invention.

[0024] Generally, the lightweight robotic vehicle **14** includes a drive unit which causes the versatile endless track **16** to rotate about the track supports **12** providing propulsion of the lightweight robotic. For example, one of the track supports can provide a friction drive interface **13** to the flexible track. Friction drive interfaces **13** provide a benefit in that the flexible track need not include gear-like protrusions on the internal surface in order to interface to the drive unit. Friction drive interface is possible for lightweight robotic vehicles because the forces involved are relatively low (as compared, for example, to large heavy vehicles such as a tank or snowmobile).

[0025] Various ways of attaching the traction pads **18** to the flexible track **16** are possible. For example, as shown in FIG. **2**, the traction pads can be threaded onto flexible track which is formed from a plurality of cables **19**. As another option, as shown in FIG. **3** the traction pads may be integrally formed with the flexible track, for example by molding the flexible track as single assembly, in accordance with an embodiment of the present invention. As another option, the traction pads may be formed of different materials and attached to the flexible track by glue, fasteners, and similar techniques. The traction pads may be removable, allowing for easy replacement or changing of the types of traction pads.

[0026] FIG. **4** illustrates a particular example of a technique for attaching the traction pads **27**, **28**, **29** to the flexible track **16** in accordance with an embodiment of the present invention. The flexible track includes a plurality of receptacles **30** into which the traction pads can be inserted. For example, the traction pads can slide or snap into the receptacles. The traction pads can have a friction fit interface to the receptacle, allowing for manual insertion and removal of the traction pads by a person. A friction fit can be appropriate for the lightweight loading conditions of small robotic vehicles because the forces placed on the traction pad are relatively small. For example, lightweight robotic vehicles generally weigh less than 100 pounds, and typically under 50 pounds, although some lightweight robotic vehicles can weight less than 20 or even 10 pounds.

[0027] The traction pads **18** can be arranged in a sequential order, for example as illustrated in FIG. **2**, although this is not essential. In other words, for three traction pad types A, B, and C, the traction pads can be arranged in sequence A-B-C-A-B-C . . . all the way around the flexible track. Alternately, the traction pads can be arranged in different orders. For example, it may be desirable to include more of one fraction pad type than other traction pad types due to differences in the traction provided. Accordingly, the traction pads may be arranged in a sequence such as A-A-A-B-C-A-A-A-B-C . . . where three traction pads of type A are provided for each traction pad of type B and type C. For example, FIG. **3** illustrates an alternate arrangement of different types of traction pads. Of course, many other arrangements are possible as will occur to one of skill in the art.

[0028] It is desirable that sufficient traction pads of each type are included so that at least one traction pad of each type is present on the ground-engaging portion of the flexible endless track at all times. This can help to ensure that adequate traction is provided at all times.

[0029] A versatile endless track **10** having two or more types of traction pads **18** can provide improved traction for a lightweight robotic vehicle **14** in a variety of conditions. Previously, endless track configurations have generally presented a uniform ground-interface profile that is a compromise design for a range of surface conditions. In contrast, the versatile endless track can include multiple traction pads, each traction pad type designed for good performance under specific conditions. For example, different types of traction pads can be defined by their differing ground-interfacing profiles. The flexible track **16** can have two, three, or more differing types of traction pads.

[0030] Various examples of traction pads will now be described, although various other traction pads will occur to one of skill in the art having possession of this disclosure. A first traction pad type can be designed to provide traction on a soft, friable surface. For example, FIG. **5** illustrates a traction pad **40** designed to help spread the weight of the lightweight robotic vehicle over an area to help avoid breaking the surface which could allow slippage of the track. The traction pad includes a low-profile projecting bar cleat **42** mounted on a substantially flat ground-interfacing surface **44**.

[0031] Other traction pad types can also be designed to provide traction on a hard, slippery surface. For example, FIG. **6** illustrates a sticky-pad **50** designed to provide a large, high coefficient of friction surface. The sticky-pad can have a substantially flat ground-interfacing surface **52** which can include grit, non-drying adhesive, or similar high coefficient of friction material. Alternately, a traction pad design **27** for use on a hard, slippery surface can include one or more suction cups (see FIG. **4**).

[0032] As illustrated in FIGS. **1**-**4**, various other traction pad types and profiles can be used, including for example, flat pads (e.g., **20**), cleats (e.g., **22**), spikes (e.g., **24**), tread patterns (e.g., **25**), saw tooth profiles (e.g., **28**) and water paddles (e.g., **29**).

[0033] Because different fraction pads are included on the versatile endless track to accommodate different conditions, in one embodiment the individual traction pad types may each be optimized to provide traction with respect to a ground surface having different traction properties. In other words, the individual traction pad types need not be compromise designs designed for more than one surface type. Thus, when designing a traction pad type for operation in sand, as an example, the performance of the traction pad in mud or hard ground may be ignored. This is possible because multiple traction pad types are included on the versatile endless track. When conditions are encountered for which one traction pad type provides poor performance, other traction pad types are likely to perform well. Thus, depending on the ground surface conditions, one type of traction pads may provide most of the traction while other types provide relatively little traction. Of course, the individual traction pads can also be designed to accommodate a range of surface conditions as well. Hence, great flexibility in the versatile endless track is obtained.

[0034] Versatile endless tracks as described above can be helpful in adapting the configuration of a lightweight robotic vehicle for a particular task. For example, different types of traction pads can be installed on a lightweight robotic vehicle depending on the environmental conditions expected for a planned operating environment of the lightweight robotic vehicle. A lightweight robotic vehicle, which is expected to operate on both solid land and on water, can include a mixture of paddle-type traction pads and cleat-type traction pads. As another example, a lightweight robotic vehicle that is expected to operate over a wide variety of surface conditions might include three or more different traction pad types, including for example, sticky-pads, short spikes, long spikes, bar cleats, suction cups, and water paddles. With a reconfigurable versatile endless track, where the traction pads are easily removed and replaced, a virtually unlimited number of different arrangements are possible.

[0035] FIG. **7** illustrates a method for configuring an endless track with traction pads in accordance with an embodiment of the present invention. The method, shown generally at **70**, includes the step of providing **72** an endless track suitable for mounting a lightweight robotic vehicle. Various materials and configurations of endless tracks are described above. A next step of the method is mounting **74** the endless track on the lightweight robotic vehicle so that a portion of the endless track is exposed for interfacing to a ground surface. Various techniques for mounting the endless track on the lightweight robotic vehicle are described above. The method also includes the step of attaching **76** a plurality of traction pads to the endless track so that at least one of each type of traction pad is included within the exposed portion of the endless track when the lightweight robotic vehicle is operated. For example, the traction pads may be placed in a sequential order as described above.

[0036] The method can include replacing at least one of the plurality of traction pads with a traction pad of a different type. For example, the lightweight robotic vehicle can be reconfigured for a different operating environment by replacing one type of traction pads with a different type of traction pads. As a particular example, consider a first configuration where the traction pads types consist of alternating suction cups and spikes, designed to provide good traction on both a smooth, hard surface and a soft, penetrable surface. The spikes might be removed and replaced with sticky pads to provide good traction on both smooth, hard surfaces and rough, hard surfaces. As another example, a first configuration having two traction pad types might be rearranged to include a third traction pad type to provide increased versatility.

[0037] Summarizing and reiterating to some extent, a versatile endless track system in accordance with embodiments of the present invention provides flexibility in the configuration of an endless track for a lightweight robotic vehicle. A mix of different traction pad types can be included which correspond to a range of expected environments, where individual traction pads provide good traction properties under different conditions. Traction pads can be removed and replaced with different traction pad types to adapt the lightweight robotic vehicle to different conditions.

[0038] The foregoing detailed description describes the invention with reference to specific exemplary embodiments. However, it will be appreciated that various modifications and changes can be made without departing from the scope of the present invention as set forth in the appended claims. The detailed description and accompanying drawings are to be regarded as merely illustrative, rather than as restrictive, and all such modifications or changes, if any, are intended to fall within the scope of the present invention as described and set forth herein.

[0039] More specifically, while illustrative exemplary embodiments of the invention have been described herein, the present invention is not limited to these embodiments, but includes any and all embodiments having modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the foregoing detailed description. The limitations in the claims are to be interpreted broadly based the language employed in the claims and not limited to examples described in the foregoing detailed description or during the prosecution of the application, which examples are to be construed as non-exclusive. For example, in the present disclosure, the term "preferably" is non-exclusive where it is intended to mean "preferably, but not limited to." Any steps recited in any method or process claims may be executed in any order and are not limited to the order presented in the claims. Means-plus-function or step-plus-function limitations will only be employed where for a specific claim limitation all of the following conditions are present: a) "means for" or "step for" is expressly recited in that limitation; b) a corresponding function is expressly recited in that limitation; and c) structure, material or acts that support that function are described within the specification. Accordingly, the scope of the invention should be determined solely by the appended claims and their legal equivalents, rather than by the descriptions and examples given above.

What is claimed and desired to be secured by Letters Patent is:

1. A versatile endless track usable by a lightweight mobile robot, the track comprising:

a flexible track configured for mounting about a plurality of track supports, and having a changing ground-engaging portion exposed for engagement with a ground surface as the flexible track is rotated around the plurality of track supports;

a plurality of receptacles contained within the flexible track; and

a plurality of traction pads inserted into and support by the plurality of receptacles,

wherein at least two different types of traction pad are included, each type of traction pad having a different ground-interfacing profile designed to provide traction with respect to ground surfaces having different traction properties, and

wherein sufficient traction pads of each type are included so that at least one traction pad of each type is present on the ground-engaging portion of the flexible track at all times.

2. The track of claim **1**, wherein the traction pads are removably supported with the receptacles and replaceable with a traction pad of a different type.

3. The track of claim **1**, wherein the traction pads snap into the receptacles.

4. The track of claim **1**, wherein the traction pads have a friction fit interface with the receptacles.

5. The track of claim **1**, wherein each of the plurality of receptacles comprises at least one hole formed into flexible track for receiving at least one corresponding post extending from a base of a traction pad.

6. The track of claim **1**, wherein the flexible track comprises an elastic belt into which the plurality of receptacles are formed.

7. The track of claim **1**, wherein the flexible track is configured to provide a friction drive interface to at least one of the plurality of track supports.

8. The track of claim **1**, wherein at least three different traction pad types are included.

9. The track of claim **1**, wherein each traction pad type is optimized to provide traction with respect to a ground surface having different traction properties.

10. The track of claim **1**, wherein the traction pad types are optimized to provide traction when loaded by a lightweight mobile robot weighing less than 100 pounds.

11. The track of claim **1**, wherein a first traction pad type is designed to provide traction on a soft, friable surface and a second traction pad type is designed to provide traction on a hard, slippery surface.

12. The track of claim **1**, wherein a first traction pad type is designed to provide traction on a firm surface and a second traction pad type is designed to provide traction on a soft surface.

13. The track of claim **1**, wherein a first traction pad type is designed to provide traction on a solid surface and a second traction pad type is designed to provide traction on a liquid surface.

14. The track of claim **1**, wherein at least one traction pad type comprises a substantially flat ground-interfacing portion having a high coefficient of friction and a second traction pad type comprises a projecting cleat.

15. The track of claim **1**, wherein at least one traction pad type comprises a projecting cleat and a second traction pad type comprises a water paddle.

16. The track of claim **1**, wherein each of the traction pad types are chosen from the group of traction pad types consisting of: a flat pad, a sticky pad, a bar cleat, a spike, a suction cup, a saw tooth profile, and a water paddle.

17. A method of configuring an endless track with traction pads comprising

providing an endless track suitable for mounting on a lightweight robotic vehicle having a ground-engaging portion and a plurality of receptacles contained within the endless track;

mounting the endless track on the lightweight robotic vehicle so that the ground-engaging a portion is exposed for interfacing to a ground surface; and

inserting the plurality of traction pads into the plurality of receptacles in an alternating sequence of at least two different traction pad types so that at least one of each type of traction pad is present on the exposed, ground-engaging portion of the endless track when the lightweight robotic vehicle is operated.

18. The method of claim **17**, further comprising selecting the at least two different traction pad types from a predefined assortment of traction pad types, wherein the at least two fraction pad types are selected to correspond to a planned operating environment.

19. The method of claim **17**, further comprising removing and replacing at least one of the plurality of traction pads with a traction pad of a different type.

20. A versatile endless track usable by a lightweight mobile robot, the track comprising:

a flexible track configured for mounting about a plurality of track supports, and having a changing ground-engaging portion exposed for engagement with a ground surface as the flexible track is rotated around the plurality of track supports;

a plurality of receptacles contained within the flexible track; and

a plurality of first traction pads removably inserted into at least some of the plurality of receptacles, each having a ground-interfacing profile configured to provide traction with respect to a first ground surface; and

a plurality of second traction pads removably inserted into at least some of the plurality of receptacles in an alternating sequence with the first traction pads, each having a ground-interfacing profile configured to provide traction with respect to a second ground surface,

wherein the first and second traction pads are selectively interchangeable with a plurality of third traction pads having a ground-interfacing profile configured to provide traction with respect to a third ground surface, and

wherein sufficient traction pads of at least two types are included so that at least one traction pad of the at least two types is present on the ground-engaging portion of the flexible track at all times.

* * * * *