SENSING SYSTEMS AND METHODS FOR MONITORING GAIT DYNAMICS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. application Ser. No. 11/346,600, filed on Feb. 2, 2006, which claims priority to U.S. Provisional Patent Application No. 60/649,226, filed on Feb. 2, 2005, the entirety of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] Embodiments of the invention relate to sensing systems and methods and, in particular, sensors for use in monitoring the gait dynamics of a user.

[0004] 2. Description of the Related Art

[0005] Millions of individuals worldwide rely on prosthetic and/or orthotic devices to compensate for disabilities, such as amputation or debilitation, and to assist in the rehabilitation of injured limbs. Orthotic devices include external apparatuses used to support, align, prevent, protect, correct deformities of, or improve the function of movable parts of the body. Prosthetic devices include apparatuses used as artificial substitutes for a missing body part, such as an arm or leg. The number of disabled persons or amputees is increasing each year as the average age of individuals increases, as does the prevalence of debilitating diseases such as diabetes. As a result, the need for prosthetic and orthotic devices is also increasing.

[0006] In order to improve operability, prosthetic and orthotic devices may be properly aligned by a trained professional, such as a licensed prosthetist. One conventional means for correctly aligning a prosthetic/orthotic device employs laser beams to determine the center of gravity of a device while being worn. Unfortunately, the use of this alignment method requires expensive equipment that is not very portable. Hence, there is a need for technology to align prosthetic/orthotic devices that is both affordable and portable. Such a technology would also be valuable for other industries that manufacture devices associated with limbs, such as clothing and sporting-equipment industries, which also lack an affordable and portable technology for properly aligning devices, such as shoes, ski boots, etc.

[0007] Some prosthetic/orthotic devices employ sensors to gather data relevant to the device. One relevant source of information is the amount of pressure placed on a prosthetic/orthotic device, such as a prosthetic foot, while walking. Unfortunately, a single conventional sensor attached to a prosthetic foot, generally, only detects either a heel strike or a toe load. Conventional sensors, generally, cannot be positioned on a prosthetic foot to measure both a heel strike and a toe load. Hence, there is a need for improved sensors for prosthetic/orthotic devices. Such a sensor technology would also be valuable for other industries that manufacture devices associated with limbs, such as clothing and sporting-equipment industries, which also lack sensors capable of being positioned on a device associated with a foot in such a way that allows for the detection of both a heel strike and toe load while walking, running, etc.

[0008] Some prosthetic/orthotic devices have sensor systems that interact with the device, causing the device to automatically adjust itself based on sensor readings. Unfortunately, conventional sensor systems do not provide efficient, cost-effective technologies for storing cumulative information regarding, for instance, a user's gait dynamics. Hence, there is a need for prosthetic/orthotic devices that store cumulative performance characteristics of the respective device. Such technology may also be valuable for other industries that manufacture devices associated with limbs.

[0009] Some prosthetic/orthotic devices provide sensory feedback to the user. One disadvantage of conventional sensory feedback systems, however, is that they involve electrical stimulus. Among other potential problems, these systems may be (or at least may appear to be) uncomfortable, unaesthetic, and unsafe. Hence, there is a need for improved sensory feedback systems. Improved sensory feedback systems may also be valuable for other industries that manufacture devices associated with limbs.

[0010] Currently, there are sensors that measure the surface strain of a material. For instance, it is commonly known to use strain gauges to measure the actual strain in the surface of a material. These strain gauges may measure the changes in electrical resistance as certain strained forces are applied to the material. As the strain gauges are attached to a material surface, the strain gauges typically measure only the strain at the material surface. There are many disadvantages to using strain gauges. For instance, conventional strain gauges do not isolate the change in resistance due to the deformations in surface to which the sensor is attached. Thus, temperature, material properties, the adhesive that bonds the gauge to the surface, and the stability of the material all affect the detected resistance. For example, in the prosthetics industry, individual prosthetic devices, such as a prosthetic foot, may be made from a variety of materials. Thus, conventional strain gauges would have to be calibrated for every foot made of a different material. Additionally, it may even be necessary to calibrate different foot devices of the same material. This unit-per-unit calibration is expensive and impractical. Another limitation of conventional stain gauges is that they are not flexible enough for certain applications, such as attachment to prosthetic feet. Conventional strain gauges measure a miniscule range of surface tension. Very flexible materials, such as carbon fiber used for prosthetic feet, exceed this range. Adapting conventional strain gauges for use with flexible devices associated with a limb, such as a prosthetic foot, may be impractical and expensive and may have an undesirable affect on the functionality of the device. Thus, there is a need for improved sensors for devices associated with a limb, such as a prosthetic foot.

[0011] No attempt is made here to catalogue all of the needs in the prior art to which embodiments of the invention are directed. It will be appreciated by one skilled in the art that the embodiments described below are directed to solving the needs mentioned above, as well as other needs not listed.

SUMMARY OF THE INVENTION

[0012] Certain embodiments of the invention relate to systems and methods for monitoring gait dynamics. In one embodiment, an intelligent foot employs a flexible sensor