when assembled is supported rotatably over the stator (not shown). The electrodes in the stator (**D1**, **D2**, **D3**) are connected to the 3-phase a-c signal source, each receiving one phase high-voltage a-c signal independently. The rotor is kept at 0 volts potential (ground). The rotary type electrostatic actuator can be turned controllably by application of the a-c signals with the $2\pi/3$ phase offset between them.

[**0036**] **FIG. 2***c* illustrates a basic theory of operation of both the rotary and linear actuators with a cutaway view of moving electrodes between two pairs of stationary electrodes (conductors above and below). As before, the rotor electrodes are grounded (0 V) while the stator electrodes are driven by high ac voltage (+V). The voltage limit depends on the breakdown characteristics of the insulating material **50***a,b* and **52**. The insulating substrates **50***a,b* and **52** are formed from dielectric materials. Notably, the configuration of the stator and rotor electrodes in **FIGS. 2***d-f* are markedly different from the configuration in **FIG. 2***b,* and they allow higher voltages at smaller geometries. This is due to the fact that each of the three electrode groups is driven at a different radial distance from the center of rotation and the difference in radial distance is sufficient to keep the three phases apart, thus allowing the narrow gaps between the electrodes of the same phase on the same radial circle. Indeed, for the geometries of interest as shown for example in **FIGS. 2***d-***2***f,* the voltage can reach 1 to 4 KV. Returning for moment to the model in **FIG. 2***c,* when the high voltage is applied, the rotor electrode strips are attracted to the stationary electrodes above and below, and although the upward and downward forces cancel each other the fringe forces pull (or rotate) the rotor as shown. As further shown in **FIG. 2***f,* the 3-phase signals are applied to the connections on the stator. The phases are offset from each other and the voltages can be sequenced to drive the rotor in either direction.

[**0037**] There is a standard scale of muscle strength called the Oxford Scale, and that scale goes from no contraction all the way up to full power. The actuator is designed to supply sufficient power to the active support device for moving higher in the Oxford scale, say, from 2 to 3 in the scale, for one who can barely move the knee, to a level of substantial power strength. Relatively speaking, although not shown in the foregoing diagrams, the stator and rotor can be stacked sequentially to form a light weight, high power, high torque actuator.

[**0038**] The battery compartment is part of the actuator or is attached to another part of the structural frame with wires connected to the actuator. Thus, unlike conventional devices this configuration is lighter, more compact, and allows better and easier mobility.

[**0039**] The control panel is part of the actuator or is attached to another part of the structural frame with wires connected to the actuator. Buttons of the control panel are preferably of the type that can be operated through clothing to allow the device mode to be changed when the device is hidden under the clothes.

[**0040**] When the invention is applied to joints other than the knee, the same principles apply. For instance, a device to aid in wrist movement has elastic bands coupling a small actuator to the hand and wrist. Joints with more than one degree of freedom may have a single device to assist/resist the primary movement direction, or may have multiple actuators for different degrees of freedom. Other potential candidates for assistance include the ankle, hip, elbow, shoulder and neck.

ROTATION OF THE TIBIA AND FEMUR

[**0041**] In a preferred implementation, the actuator is of a rotary design type with the center of rotation of the actuator located close to the center of rotation of the knee joint. According to the knee anatomy, in flexion, the tibia lies beneath, and in line with, the midpoint of the patella (knee cap). As extension occurs, the tibia externally rotates and the tibia tubercle comes to lie lateral to the midpoint of the patella. When the knee is fully flexed, the tibial tubercle points to the inner half of the patella; in the extended knee it is in line with the outer half. Namely, the knee anatomy is constructed in such a way that a point on the lower leg does not move exactly in a circular arc. Thus, in order for the circular movement of the actuator to match the movement of the leg, the coupling from the rotor to the lower brace requires either an elastic coupling or a mechanical structure to couple the circular movement of the actuator with the near-circular movement of the portion of the brace attached to the lower leg.

[**0042**] **FIGS. 3***a* and **3***b* show a coupling mechanism that compensates for the movement of the center of rotation as the knee is flexed. **FIG. 3***a* shows the knee flexed at 90 degrees, and **FIG. 3***b* shows the knee fully extended. The center of rotation of the actuator is centered at the upper end of the lower leg (tibia) when extended, but shifts towards the posterior of the tibia when the knee is flexed. The sliding mechanism allows the actuator to apply assistance or resistance force at any angle of flexure.

[**0043**] If the center of rotation of the actuator is located a distance away from the joint, other coupling mechanisms can be used to couple the actuator to portion of the brace on the other side of the joint. The coupling mechanism can be constructed using belts, gears, chains or linkages as is known in the art. These couplings can optionally change the ratio of actuator rotation to joint rotation.

[**0044**] In an alternate implementation using a linear actuator, the linear actuator has the stator attached to the femur portion of the brace and the slider is indirectly connected to the tibial part of the brace via a connecting cable stretched over a pulley. The center of rotation of the pulley is close to the center of rotation of the knee. With this arrangement, a second actuator is required to oppose the motion of the first actuator if the device is to be used for resistance as well as assistance, or for flexion as well as extension.

ELECTRONICS AND CONTROL SYSTEM BLOCK DIAGRAM AND OPERATION

[**0045**] **FIG. 4** is a block diagram showing the electronics and control system. The operation of the device is controlled by a program running in a microcontroller **402**. To minimize the physical size of the control system the microcontroller is selected based on the scope of its internal functionality. Hence, in one implementation, the microcontroller is the Cygnal 8051F310, although those skilled in the art will recognize that many current and future generation microcontrollers could be used. In addition, some of the internal functions of the 8051F310 could be implemented with external components instead of internal to the microcontroller.