Immersive Desktop Display with Axial Muscle Navigation and Control

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In daily life when we want to see something, we just move our bodies around by walking, bending, turning and so forth until we can see it. It is by such naturally coordinated movement that we change our present view-point to some new, desired view-point. While we have very sophisticated and naturally integrated human hardware for dealing with the physical-world, we have no such natural interface to support behavior in simulated or virtual-worlds. Current systems such as head-mounted displays, tactile feedback devices, instrumented gloves and body suits and so forth, are improvements to the art of more closely connecting the human to a non-physical world. They provide proprioceptic and other state-of-the-body position and orientation information to the user as useful feedback for control of virtual movement. Unfortunately, many of these current systems suffer many drawbacks when considered for non-experimental use.

The Axis Display System described here offers a number of advantages including improved intuitive and effective feedback control in a small space. The Axis Display System provides a way of yoking and measuring the exertion of the area-of-visual-interest orienting muscle groups while constraining the actual movement of the muscles. It should be pointed out that this paper describes a theory of operation which is but a hypothesis derived from first hand qualitative experiences.

As defined here, the area-of-interest or view-point orienting muscle groups include, generally speaking, those having either their origins and or insertions on the spinous and or transverse processes of the vertebral column. These are informally referred to here as the Axial Muscle Group. They also include some muscles that have their insertions on the calvarium and on the pelvic bones. These muscles act to produce head movement and thus, control of the view-point, in the various rotational degrees of freedom. The yoking of the view-point orienting muscle groups to the position or force sensors as described here provides force feedback information for control of the virtual-world without requiring full physical-motion from the user. The Axis Display System also provides for mapping this exertion to the rate of and direction of movement in the virtual-world.

The advantages and working of the Axis Display System can be better explained and understood by the following consideration of three neuroanatomical and structural principles of the body.

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First, the vertebal column is substantially fluid and flexible. Generally speaking, the intersection of a rotation plane and its axis of rotation can occur nearly anywhere along the vertebral column from the lumbar area up to the base of the skull. For example, when humans pan or orient towards an area-of-visual-interest, this rotation could occur at the neck or it could occur at the level of the shoulders while keeping the neck stiff or it could occur at the level of the hips while keeping the neck and shoulders stiff or some combination of these movements. The same is true of pitching and rolling motions.

Second, the muscles which move and orient the head and trunk send special sensory information to the brain while they are contracting. This special sensory information permits knowledge of one's orientation independent of other sensory cues such as sight or balance. Therefore, simply by the action of the muscles that orient the head and trunk we can know when we have substantially achieved an orientation.

Lastly, voluntary muscular coordination is driven by our perception of achieving an end-point or goal of a muscular movement. This means we tend to exert as much force as required, but only enough force to efficiently reach our desired end-point. This has been called the law of minimal spurt action. (See Essentials of Human Anatomy, Woodburne, Oxford Press, 1978, p15.)

The Axis Display System capitalizes on these three principles. Because of the fluidity of the vertebral column, the Axis Display System effectively yokes the movement of the view-point orienting muscles in the physical-world to movement in the virtual-world without the disadvantages of a head-mounted display. Therefore, to orient toward an area-of-visual-interest in the leftward portion of the virtual-world, the user simply and naturally activates the muscles that would be used to orient left in the physical-environment. At the same time, the effect of virtual-motion as the virtual-view moves toward a new virtual-area-of-interest is compelling because while the muscles are contracting, there is special sensory information sent to the brain telling it that such movement should be occurring. This movement is confirmed by the smooth flow of images in the display depicting movement toward an area-of-visual-interest until the area-of-visual-interest is perceived. Hence the perception of natural and intuitive bodily movement has occurred eventhough only constrained bodily movement has actually taken place.

The Axis Display System not only provides means for yoking the view-point orienting muscles to appropriate virtual-motion but also provides means for mapping the rate of and direction of this virtual-motion to the actual physical-force applied by the muscles to the device. In addition to the above principles, we have observed a non-linearity of muscle exertion and the expected change of virtual-motion. There is support in the literature for the thesis that the amplitude of postural change is logarithmically proportional to virtual-image velocity (see Boff and Lincoln, Engineering Compendium: Human Perception and Performance, AAMRL, Wright-Patterson AFB, OH, 1988)

As an example of common practice, the user may is seated in front of the Axis Display System with his or her two hands grasping the handles on the Axis Display Head. The arms are ordinarily substantially rigid so that the user can forcibly interact with the computer substantially using the area-of-visual-interest orienting muscles of neck and trunk, although aftertime the user will tend to modify this posture. This force information is fed to a computer where commands are generated which control motion in the virtual world. In this way, the user manipulates his virtual area-of-visual-interest so that if, for example, the user physically turns left the visual presentation to the user corresponds to the virtual-world to the left. When user sees what is desired, that is, reaches his area-of-visual-interest, these muscles begin to relax and the virtual-motion is accordingly slowed to a standstill.

The Axis Display System provides a way of mapping the constrained-motion exertion of the area-of-visual-interest orienting muscle groups with an appropriate and expected rate of change in area-of-visual-interest in the virtual-world. We have been impressed with effectiveness of the system to pair muscle exertion with apparent virtual-motion thereby providing free movement in a virtual-world without having to leave one's chair.