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Ultrasonic Motion Analysis System for Estimating Segment's Stabilization During Dynamic Condition

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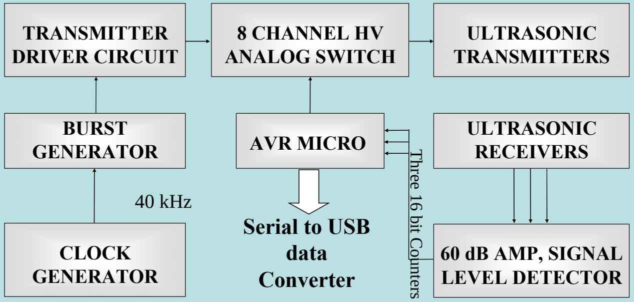
Abstract

While the function of central and peripheral nervous system decreases (caused by aging, vestibular deficiency or stroke), maintaining of body stability become hard. Studies indicate that movement coordination of axial segments (head, thorax, and pelvis) in a dynamic state such as walking disrupted in these pathologic conditions. In recent years goniometry and cinematography have been widely used to measure active or passive range of motion (ROM) in asymptomatic adults. The aim of this investigation is to design and implement a new method by evidence based approach for estimating the level of impairment in segment stability and improvement after treatment by measuring quality or quantity of movement among axial segments. Ultrasound based coordinate measuring system (CMS) can continuously measure motion in three dimensions during the course of time in a dynamic condition. The measuring procedure is based on the travel time measurement of ultrasonic pulses that are emitted by miniature transmitters (markers) to the three microphones built into the compact device.

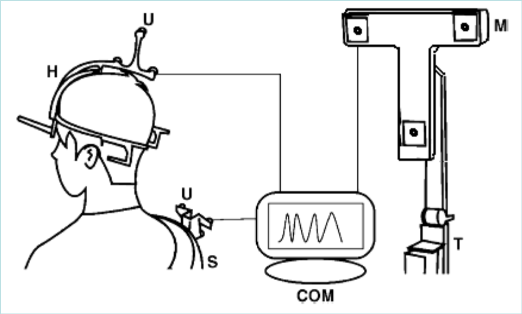
Instrumentation

Ultrasound based coordinate measuring system (CMS) can continuously measure motion in three dimensions during time of dynamic conditions. The experiment procedure is based on measuring travel time of ultrasonic pulses that are emitted by markers to receiver stand and calculating distance of markers from receiver base. This system consist electronic hardware, data acquisition and processing software and two set of triple markers on the head attachment and the shoulder cap. Electronic section include: 40 kHz oscillator, PRF pulse generator, sensor drivers, 8 channel high voltage analog switch, 60 dB gain amplifier, signal level detector and CPU. The transmitter sends out a burst of ultrasound and the delay it takes for this burst to reach the receiver is recorded. From this delay the distance between the transmitter and receiver can be calculated from: d=t×vs. Sound velocity can be approximated by vs = 331.5+0.6 Tc where Tc is the air temperature in degree centigrade.

The main part of electronic circuit is an AVR microcontroller (ATMEGA128) which control high voltage analog switches of transmitter that transmit sound waves periodically. On the other hand, this micro measures time of receiving sound waves to three ultrasonic receivers which are fixed on a T-shaped base



Block diagram of the ultrasonic gait analysis system



The experiment setup of ultrasonic motion analysis system

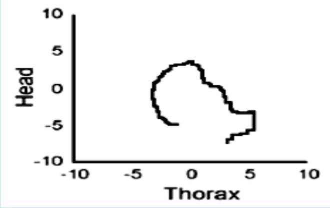
Ultrasonic marker which install on shoulder cap

Markers

The triple marker set includes three ultrasonic transmitters with frequencies of 40 kHz that were used to measure the kinematics of cervical motions.

Results

Inter-segmental coordination was analyzed in two ways: first, by pattern analysis of the angle-angle plots, also cyclographs, between head and thorax segments.



Angle-angle plot (cyclograph)

The second is by cross-correlating between head and thorax angles. The CCF was assumed to extract the temporal relationship between head and shoulder movements. Average CCFs were calculated for each subject and expressed by the CCF coefficient peaks. Maximum positive CCF coefficients correspond to coordinated movements of the head and shoulders in the same direction, whereas minimum negative CCF coefficients correspond to head and shoulder variations in opposite directions.

AI aimed to compare the stabilization of the head with respect to the shoulder and to space. The AI was expressed as follows:

$$AI(H) = \left[\sigma^2\left(\theta_r^H\right) - \sigma^2\left(\theta_a^H\right)\right] / \left[\sigma^2\left(\theta_r^H\right) + \sigma^2\left(\theta_a^H\right)\right]$$

Where σ^2_a is the absolute angular deviation and σ^2_r is the relative angular deviation. Positive and negative values of AI indicate that the head is preferentially stabilized in space and on the shoulders, respectively.

Discussion

For balance control, studies have suggested two strategies. First head stabilization strategy (HSS); in this strategy head movement is independent from trunk movement and stabilized itself with respect to vertical position. Based on this presupposition AI and cross correlation between two groups of coordinates data of head and trunk in a given time become near to +1 and 0 respectively. The second strategy is head stabilization on trunk (HST); in this strategy head movements follow the trunk movements, or in better word the movement of head and trunk is interrelated. AI calculation become near to -1 and cross correlation analysis gets far from 0.