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Analysis and Design of Exo-Skeleton System Based on Multibody Dynamics

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Abstract : With the aging process, many people start suffering from the problem of weak limbs resulting in mobility disorders and loss of sensory and motor function of limbs. Wearable robotic devices are viable solutions to help people suffering from these issues by augmenting their strength. These robotic devices, popularly known as exoskeletons aides user by providing external power and controlling the dynamics so as to achieve desired motion. Present work studies a simplified dynamic model of the human gait. A four link open chain kinematic model is developed to describe the dynamics of Single Support Phase (SSP) of the human gait cycle. The dynamic model is developed integrating mathematical models of the motion of inverted and triple pendulums. Stance leg is modeled as inverted pendulum having single degree of freedom and swing leg as triple pendulum having three degrees of freedom viz. thigh, knee, and ankle joints. The kinematic model is formulated using forward kinematics approach. Lagrangian approach is used to formulate governing dynamic equation of the model. For a system of nonlinear differential equations, numerical method is employed to obtain system response. Reference trajectory is generated using human body simulator, LifeMOD. For optimal mechanical design and controller design of exoskeleton system, it is imperative to study parameter sensitivity of the system. Six different parameters viz. thigh, shank, and foot masses and lengths are varied from 85% to 115% of the original value for the present work. It is observed that hip joint of swing leg is the most sensitive and ankle joint of swing leg is the least sensitive one. Changing link lengths causes more deviation in system response than link masses. Also, shank length and thigh mass are most sensitive parameters. Finally, the present study gives an insight on different factors that should be considered while designing a lower extremity exoskeleton.

Keywords : lower limb exoskeleton, multibody dynamics, energy based formulation, optimal design
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