# Analysis of Human Dynamics applying Passive Motion

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Analysis of human motion is very important in the field of kinesiology. The results of analysis are applied to rehabilitation, sport training and so on. In general, human motion is measured or estimated from physical signals (motion data such as acceleration, velocity and position, force data such as forces and torques and so on) and physiological signals (electromyogram, electrocardiogram and so on). Many researchers have been studying human motion by measuring these signals.

Analysis of human motion can be divided into two methods from a viewpoint of dynamics. One is the method based on voluntary motion that human subjects move with own intention. The other is the method applying passive motion that human subjects are moved by applied external forces. In the most researches on human dynamics, the former method has been utilized so far even though there are several drawbacks. On the other hand, the latter one can become very useful if some problems are overcome.

In this paper, we propose an experimental system and apply advanced measurement and control methods in order to solve the inherent problems on human motion analysis with passive motion. At first, we developed a new system based on a parallel wire driven mechanism and Iterative Learning Control (ILC) to estimate the human joint torque in passive motion. It is experimentally confirmed that ILC can realize arbitrary human motion with high precision and the estimated torques have high repeatability at the same motion. These results mean that inverse dynamics problem can be solved in arbitrary motion without dynamics models and parameters of the human subject. The obtained joint torque contains the components from viscosity and elasticity of muscles, tendons, and skins as well as rigid links. It is a problem with the method of passive motion. Therefore, at second we introduce Time-Scale Transformation (TST) to decompose the obtained torque pattern into the component form rigid links and the component from viscosity and elasticity of muscles, tendons, and skins. The usefulness of the decomposition method is demonstrated through some experimental results. Finally, we claim that the torque component form the rigid links is effectively used for inertial parameter estimation because the torque component form viscosity and elasticity of muscles, tendons, and skins is eliminated. It is experimentally shown that the parameters of a human upper limb are estimated with high accuracy.