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Camera Captured Data Control of a Robot for Disabled People

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Abstract

This robot is designed for disabled people who wish to live as the others. Camera captured data of a healthy praying person will be utilized to provide the required joints rotary motions of the proposed robot. Then this data will be transformed to joint angular trajectories. Joint trajectories necessary to realize the required motion will be used on robot motion controls. One of the most important control problem of humanoid robots is the efficient calculation of correct joint angles for a given space trajectory. To realize the motions of the people on the robot, PID controls will be applied to servomotors to generate the correct positions of the leg joints. The success of the control of the given mechanism will be tested. The result of the simulations would also be extended to animations of a praying person to provide some educational material about praying.

Key words: Camera captured data, PID control, disabled people, lower limb, servo motor

1. Introduction

Technological developments and other scientific studies should focus on how the human being could be better served with the outputs of these activities. By considering all of the holly book's directions [1-3], it's clear that technological innovations and scientist should take care of disabled people to help them to make their prayer as well as they desired.

Especially for the people who were healthy before but lost some body motion capabilities because of some accidents or severe illness, praying as he or she did before is very precious. Therefore, implementations of disabled body motions by means of electromechanical systems are very important. In this paper, a complete robotic system control for lower limb disabled people is designed and the success of the system is discussed with simulations. Here, a sample data is applied to the robotic system.

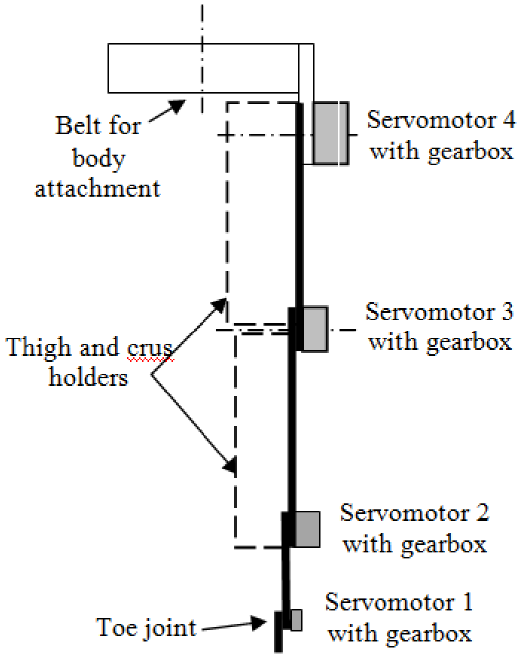

Figure 1. Schematic representation of the robot

The necessary data belonging to different motions of the people may be produced by the same way. Then by using body joined robotic system, all the disabled joints would be activated. These data may be extended to perform all of the daily activities of a person. For example, walking, running and sitting activities may also be uploaded to the robot's memory. Any required motion may be selected from the input module of the system when needed. The upper limb components of the body would also be suited with similar electro mechanical systems. Although this body wearable robotic system is realized for a lower limb disabled people it's possible to use this study for educational purposes at the same time. For this reason, simulations may be improved and utilized to educate the children about how to make the required motions for some physical exercises. So, the simulation results of this study will be available to adapt to some physical education show material that will be interesting and exciting for the kids.

This study is organized as follows. First of all, the camera records of a healthy praying people are recorded by using reflectors replaced on the hip, knee and ankle joints. By using the camera captured data and the software provided [4] the x-y positions of the reflectors are determined. These are the Cartesian trajectories of the joints to be controlled with respect to X-Y fixed reference frame. Later, hip, knee, ankle and toe joint angular motions are calculated by using these values and modified. These position vectors are introduced to the controllers of the servomotors as the reference joint angular positions in the model of the overall control system. Simulation time is adjusted as the camera recording time. As a second step, PID control system is designed to drive the joint servomotors to realize the praying motions.

Today's software tools for modeling robotic mechanisms enable researchers to design the overall system by using provided toolboxes and see the success of the considered system. Like many of the others, advantages of simulation in robotics and in different fields of robotics are also figured out by Zlajpah [5]. In this study, the powerful tools are utilized to model, simulate and validate the system as applied by Ankarali to gait modeling [6].

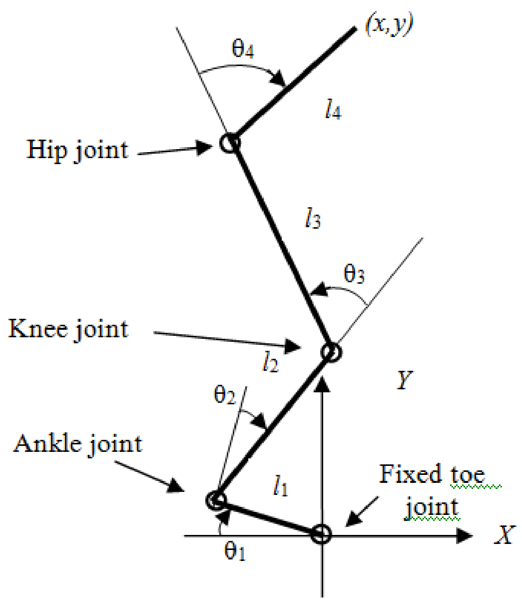

Figure 2. Joint positions and kinematic parameters

2. Generating the Joint Angular Trajectories

2.1. Camera captured data with joint reflectors for planar motion

Some of the surveys in literature about the advances in human motion capture and analysis [7] imply that the method for obtaining human motions realized in this work is common. In this study, the kinematic data used were collected using five reflective markers placed on big toe, ankle, knee, hip and shoulder joints of the right side of the body of a 41 year old healthy male subject praying at a selected velocity. Images of one *rak'at* were captured by a video camera perpendicularly located at 4m to the sagittal plane of praying space. In order to obtain 2D position data, markers were tracked at 25 Hz using the HUBAG motion analysis software [4]. Kinematic data were filtered at 6 Hz low pass digital filter and the joint kinematics was calculated on sagittal plane. The camera captured data for the marker placed points were then converted to (x,y) coordinates of the previously marked points with respect to a fixed reference coordinate frame. Later the angular motions of the joints are calculated.

2.2. Conversion of joint angular motions to polynomial trajectories

Positions of the markers data are modified to produce the angular positions of the hip, knee, ankle and toe joints for one *rak'at* by using inverse tangent relations between neighboring points on the same link. So the necessary angular position data to derive the servomotors assembled to the joints of the robot were generated for the praying motion and given in Fig 3.

3. PID Control System Design

The characteristics of the servomotors selected to drive the toe, ankle, knee and hip joints are given in Table 1. These values given for the servomotors in the manufacturer catalogue [8] are used to tune the PID parameters and given in the Table 2. The mathematical model of a PID controller can be written as [9].

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \quad (1)$$

Here, K_p, K_i and K_d are the proportional, integral and derivative gain constants respectively. *e(t)* represents the error signal which is the difference between the reference input signal and the feedback signal coming from the encoder. By using this relation, PID controller can be designed. Mathematical model of the servomotor is studied in detail [9, 10] and can be represented as a block diagram given in Fig. 5 which includes a disturbance input. Here, L is the inductance, R is the resistance, J_m and B_m are the moment of inertia of the motor and the viscous friction coefficient respectively. Input to the motor is the voltage $V(s)$ and the output of the electrical block is the current $I_a(s)$. K_i is the torque constant, different than used in Eqn. 1. The output of the block diagram is the angular position of the servomotor's shaft, $\Theta_m(s)$. τ/n is the disturbance input. It is the torque coming from the inertia effect of the link and can be calculated through dynamic equations of motion [11-13].

Table 1. Technical characteristics of the selected servomotor and the gearboxes.

Motor Data	*Toe joint*	*Ankle joint*	*Knee joint*	*Hip joint*
Type of the motor	**EC 60 Ø60 mm, brushless, 400 Watt, with Hall sensors**			
Nominal voltage (V)	24			
Nominal speed (rpm)	3100			
Nominal torque (mNm)	830			
Nominal current (mA)	5.85			
Max. efficiency (%)	85			
Characteristics				
Terminal resistance (Ohm)	1.03			
Terminal inductance (mH)	0.82			
Torque constant (mNm/A)	147			
Speed constant (rpm/V)	65			
Mechanical time constant (ms)	3.98			
Rotor inertia (gcm^2)	891			
Gearhead Data				
Reduction	300:1	1200:1	800:1	300:1

Reference input trajectories of the servomotors, PID controllers, servomotor block diagrams and the model of the lower limb of a human constitutes the general structure of the system model. The simplified block diagram of the mentioned system is given in Fig. 4.

Table 2. Tuned PID parameters

Joint / Gain	*Hip joint Servomotor*	*Knee joint Servomotor*	*Ankle joint Servomotor*	*Toe joint Servomotor*
Proportional gain	49501	132004	198006	49501
Integral gain	284484	758626	1137939	284484
Derivative gain	91	244	366	91

5. Simulations

The controllers, servomotors and the joints of the model of the simplified human being are joined to each other. Previously generated reference angular trajectories for the prayer motion are received from a data block and introduced to PID controllers of each servomotor. Only one servomotor with different gear combinations is selected by considering static torque requirements of the mechanism. Considering static design conditions, calculations of the torques at the joints are made easier.

The calculated static torques for critical positions of the robotic mechanism to drive foot, calf, thigh and trunk are 200 Nm, 1000 Nm, 630 Nm and 210 Nm respectively. The necessary data identifying the servomotor is taken from the related web page [9] for the selected servomotor and gearboxes and given in Table II. The physical properties, like lengths and mass of the links of the camera recorded male are also tabulated in the related code. The mass of the foot is 0.265 kg, calf is 3.6550 kg, thigh is 8.7550 kg and half of the trunk is 21.5475 kg. The length of the foot is 0.265 m, calf is 0.395 m, thigh is 0.405 m and the trunk is 0.545 m.

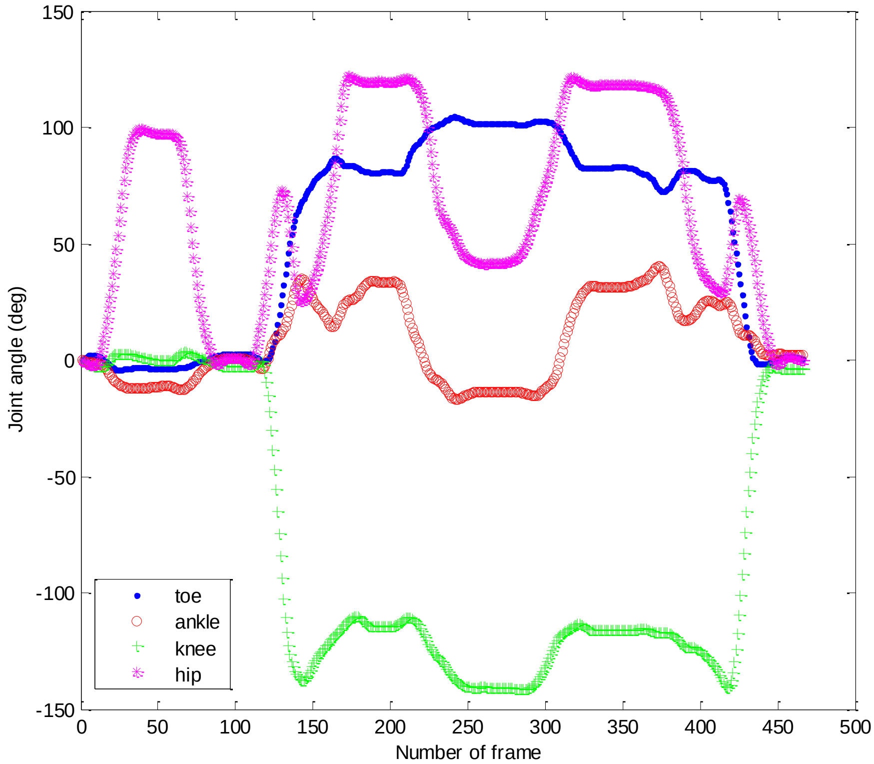

Figure 3. Joint positions of foot, calf, trunk and thigh links angular positions from camera captured data for each 0.04 s.

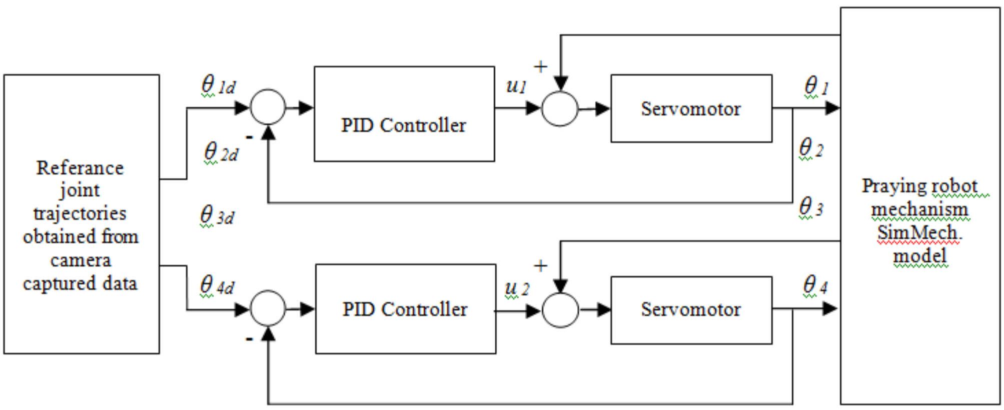

Figure 4. Overall control block diagram of the system.

The simulation time is adjusted as the same as the camera recording time where 466 captures are taken with 0.04 s interval. First of all, all the controllers are tuned by using tuning properties of the controller blocks and the optimum values of the gains obtained are given in Table 1. The performance of the controllers on trajectory tracking of the joint angular motions is shown in Fig. 6. The sampling time of the simulation is fixed to 0.002 s which must be shorter than the mechanical time constant of the servomotor for a stable running. Some snapshots taken from this animation machine are given in Fig. 7. This figure shows the motion of the robot from starting position to the end of one rak'at for some specially selected instants.

Conclusion

For praying purposes, a specially designed robot for lower limb disabled people is studied by means of simulations. The robot is a wearable type and assumed to be fastened to the body and the links so that the whole body functions like a healthy human during praying. The simulations show that such a robotic mechanism is possible to let a disabled person pray like the healthy one with all required motions to complete the prayer. The camera captured data without control belonging to a healthy person is given in Fig. 3 and the same motions from the designed robotic control system are obtained as given in Fig. 7.

Although the camera captured motion analysis is done only for one rak'at prayer of lower limb disabled people, the resulting simulations declare that the same modeling procedure is available for other limbs and also for different motions. Fig. 6 shows that the resulting performance of the tuned PID controllers on trajectory tracking of the servomotors is excellent. The maximum error between reference inputs and the realized outputs of the servomotors is about 1.5 deg. which is acceptable for this type of application.

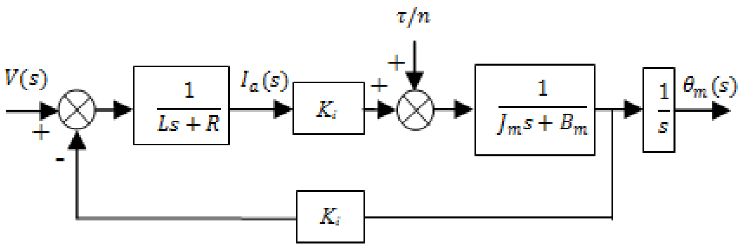

Figure 5. Block diagram of a servomotor with a torque disturbance.

For the angular motions of the joints, the same servomotor with different gear ratios proposed to use for simplicity of the complete system. If the real robotic system is considered to manufacture, in that case, a number of different design constraints would be taken into consideration and more appropriate selections may be done. Instead of simple link representations of the body parts, as seen in Fig. 7, the 3D modeled assembly of the robot may be further used in simulation by transporting the CAD assembly design of the robot to other simulation environment. By this way, a real prayer robot animation would be possible and that will be able to provide some funny teaching materials for the kids to explain how to pray.

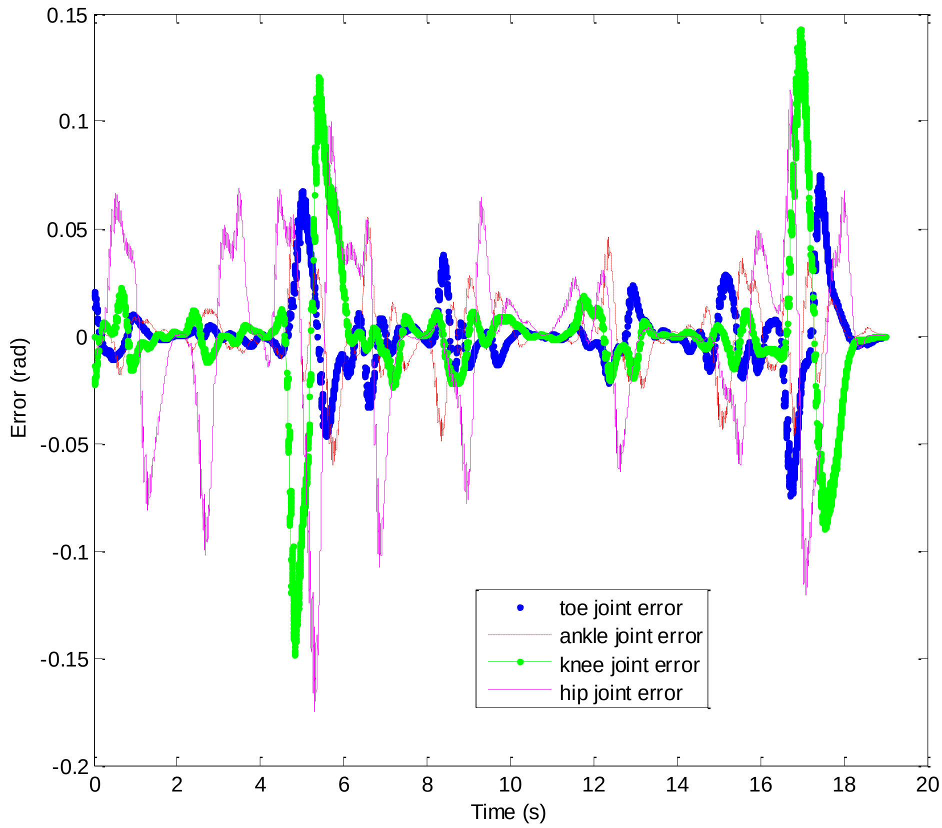

Figure 6. Trajectory tracking errors of the joints.

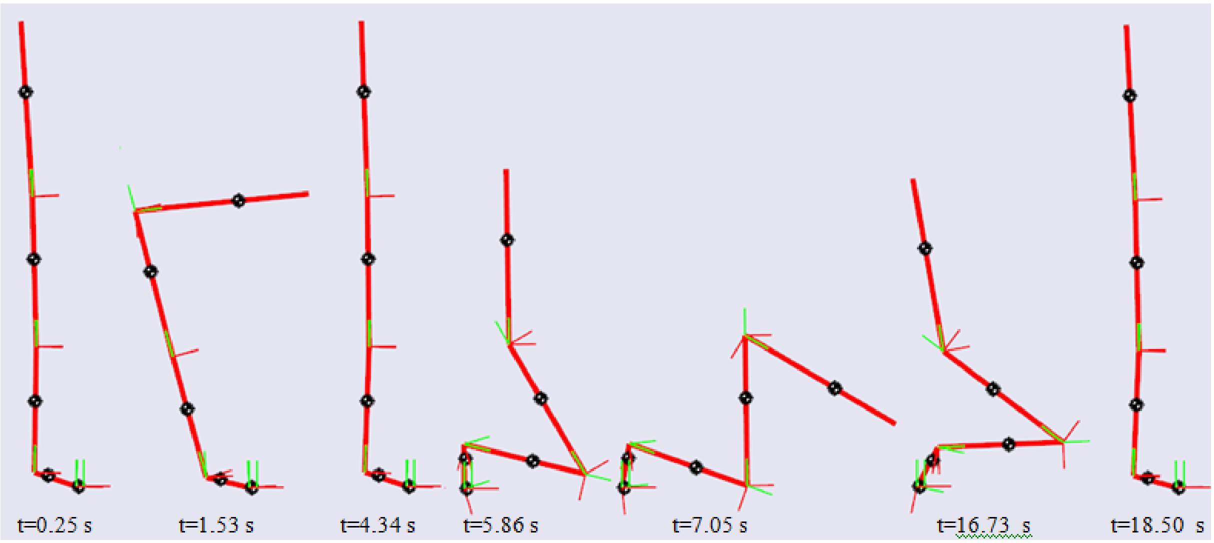

Figure 7. Some captured views from simulation between beginning position to last standing position for one rek'at.

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