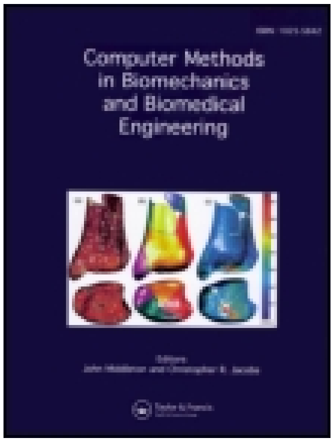

Computer Methods in Biomechanics and Biomedical Engineering
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gcmb20

A new experimental set-up based on a parallel cable robot for analysis and control of human motion

S. Bennour [a] , M. Harshe [b] , L. Romdhane [c] & J.-P. Merlet [b]

[a] Laboratoire Génie mécanique , École Nationale d'Ingénieurs de Monastir , Monastir , 5019 , Tunisia

[b] Equipe de Recherche COPRIN, INRIA, Sophia Antipolis , 06902 , Sophia Antipolis , France

[c] Laboratoire Génie mécanique , École Nationale d'Ingénieurs de Sousse , 4054 , Sousse , Tunisia

Published online: 24 Aug 2011.

Computer Methods in Biomechanics and Biomedical Engineering
Vol. 14, No. S1, August 2011, 83–85

A new experimental set-up based on a parallel cable robot for analysis and control of human motion

S. Bennour[a]*, M. Harshe[b], L. Romdhane[c] and J.-P. Merlet[b]

[a]*Laboratoire Génie mécanique, École Nationale d'Ingénieurs de Monastir, Monastir 5019, Tunisia;* [b]*Equipe de Recherche COPRIN, INRIA, Sophia Antipolis, 06902 Sophia Antipolis, France;* [c]*Laboratoire Génie mécanique, École Nationale d'Ingénieurs de Sousse, 4054 Sousse, Tunisia*

Keywords: cable-based parallel manipulators; walk analysis; inertial sensors; knee kinematics

1. Introduction

Analysis of human walking has been the subject of various studies. Sutherland (2002) provides a comprehensive review of clinical gait analysis in terms of kinematics. The movement of the tibio-femoral has been studied and a review of its kinematics is discussed in the study of Freeman and Pinskerova (2005).

The techniques used for motion analysis were quite varied. Studies have made the comparison between the use of markers in the form of pins attached to the intra-cortical and those placed on the skin to determine the human motion bones. The markers placed on intra-cortical provide data with minimum errors, but the process is heavy and cannot be reproduced on most patients. Magnetic resonance (MR) and X-rays were used to capture the poses and the calculation of joint angles (McWalter et al. 2010). These methods are limited to static experiments and give an incomplete picture about the behaviour of a joint of the lower limb (Lavoie et al. 2008). Some studies use a dynamic MRI in real time and *in vivo* (Seisler and Sheehan 2007). Owing to the high cost of MRI, a 3D motion capture based on videos and multi-camera detection of markers was used to obtain the 3D human motion (Lu et al. 2008). A widely used technique consists in attaching inertial sensors (accelerometers) on the limbs of patients (Cooper et al. 2009). These studies suggest that inertial sensors offer a relatively inexpensive way to control the movement of the knee. Other studies have focused on the use of parallel mechanisms for modelling and measuring the movement of human joints (Saglia et al. 2009). Although these studies provide a good image of the movement of the knee, few from these studies have the comparison of all possible approaches or comparison with a simulation of a built model.

Therefore, the aim of this study was to propose a complete experiment starting from analysis to testing on patients through its anatomical model. The interest is to have a tool able to compare the progress gained experimentally in a test conducted on a treadmill and that obtained by simulation from a built model.

The final aim of this study was to provide therapists with an assessment tool with assumptions for rehabilitation exercises for walking using data from the trajectories described by the various joints of the lower limb.

2. Modelling

Figure 1 shows our proposed model of the device for the analysis of walking on a treadmill. This model was built using the software ADAMS. The human body model was taken from Dezignworks (http://www.dezignstuff.com/blog/?tag=mannequin). During the exercise, the patient's left tibia and femur are attached to seven passive cables of a parallel robot with two collars adjustable in position and orientation.

3. Experimental set-up

Our approach to measure joint movement (knee) is to implement surface motion sensors which are attached to the collars. The collars are serial chains and in each link a force sensor allows one to measure the force between the collar and the skin. Accelerometers are attached to each collar and 12 motion capture cameras allow the determination of the 3D location of markers attached to the collars. Pressure pads in the shoes allow the measurement of the force distribution for the left foot and the right one.

Overall, over 200 sensors are used to measure the limb motion. Figure 2 shows the implementation of the measurement system to passive cables, connected to the tibia by the collars and the structure of the robot Marionet. The location and orientation of the collars depend on the patient's anatomy and the motion to be achieved.

*Corresponding author. Email: sami.bennour@enim.rnu.tn

ISSN 1025-5842 print/ISSN 1476-8259 online

DOI: 10.1080/10255842.2011.592372
http://www.informaworld.com

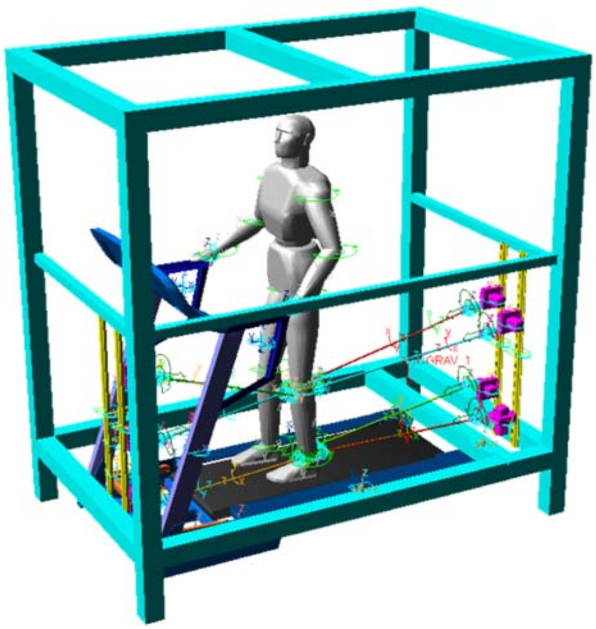

Figure 1. 3D modelling of the control and analysis of human walking: structure of the robot Marionet, measuring system-based sensors passive cables.

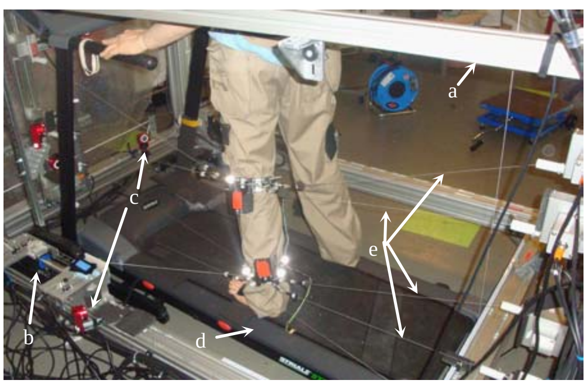

Figure 2. Experimental set-up: (a) structure of robot Marionet, (b) actuators for Marionet, (c) cameras for optical motion capture, (d) treadmill and (e) passive cables.

4. Results and discussion

To obtain a walking movement, we drive the joints of the lower limb using specified trajectories (http://www.c-motion.com). The positions described by the tibia during the simulation and variations in the cable lengths are given by the simulation using ADAMS. To validate our model, we compared the experimental results with those given by our ADAMS model. This comparison was limited to the simple case of the flexion–extension of the knee (Figure 3).

The simulation results represent an interesting support to arrange the tasks for the experimental tests. For example, variations in the lengths of the cables will help to choose the best site locations for the passive sensors.

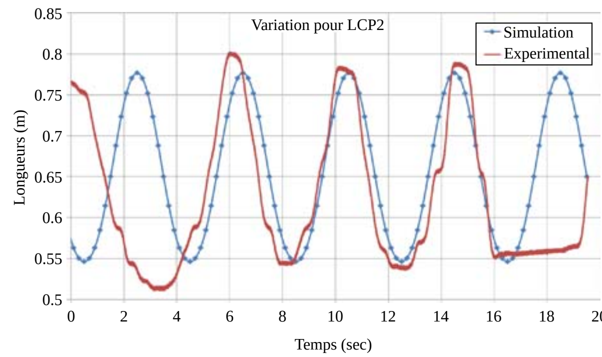

Figure 3. Variation of the length of a passive cable (cable 2) during flexion–extension of the knee.

Moreover, the measurements obtained experimentally can be used by the model to simulate and analyse the movements made by a patient. To implement this idea, a validation comparing the simulation results with those measured experimentally is recommended.

5. Conclusions

We have described in this study our method to develop the tools to solve problems related to the analysis of the human movement. Modelling is an important task when controlling the movement of the lower limbs during walking. A manipulator-type parallel cable robot, instrumented with sensors, is used to validate the results obtained by simulation.

Our aim for future experiments is to use a large number of sensors to collect all possible data, while following a given human movement. With this set of multiple measures and redundant data, we can make general assumptions for a joint. The latter will be treated as a joint with six degrees of freedom, to measure all movements, even those with low amplitudes.

In addition, as our cable robot has a kinematic structure, which can be adapted in a simple way for any application, it encourages us to develop a functional structure for the rehabilitation of the lower limb using the active cables.

References

Cooper G, Sheret I, McMillian L, Siliverdis K, Sha N, Hodgins D, Kenney L, Howard D. 2009. Inertial sensor-based knee flexion/extension angle estimation. J Biomech. 42: 2678–2685.

Freeman MAF, Pinskerova V. 2005. The movement of the normal tibio-femoral joint. J Biomech. 38:197–208.

Lavoie F, Laplante M, Duval N, Doré S, de Guise JA. 2008. Gesture as an important factor in 3D kinematic assessment of the knee. Knee Surg Sports Traumatol Arthrosc. 16:64–70.

Lu T-W, Tsai T-Y, Kuo M-Y, Hsu H-C, Chen H-L. 2008. *In vivo* three dimensional kinematics of the normal knee during

active extension under unloaded and loaded conditions using single-plane fluroscopy. Med Eng Phys. 30:1004–1012.
McWalter EJ, Macintyre NJ, Cibere J, Wilson DR. 2010. A single measure of patellar kinematics is an inadequate surrogate marker for patterns of three-dimensional kinematics in healthy knees. Knee. 17:135–140.
Saglia JA, Tsagarakis NG, Dai JS, Caldwell DG. 2009. A high-performance redundantly actuated parallel mechanism for ankle rehabilitation. Int J Robot Res. 28(9): 1216–1227.
Seisler AR, Sheehan FT. 2007. Normative three-dimensional patellofemoral and tibiofemoral kinematics: a dynamic, *in vivo* study. IEEE Trans Biomed Eng. 54:1333–1341.
Sutherland DH. 2002. The evolution of clinical gait analysis. Part II kinematics. Gait Posture. 16:159–179.