Medical Engineering & Physics 34 (2012) 1433–1440

Contents lists available at SciVerse ScienceDirect

Medical Engineering & Physics

journal homepage: www.elsevier.com/locate/medengphy

Robust femur condyle disambiguation on biplanar X-rays

Antoine Serrurier[a,*], Sergio Quijano[a], Remy Nizard[b], Wafa Skalli[a]

[a] Arts et Metiers ParisTech, LBM, 151 bd de l'Hopital, 75013 Paris, France
[b] Department of Orthopaedic Surgery, Hôpital Lariboisière, Assistance Publique des Hôpitaux de Paris, 75010 Paris, France

ARTICLE INFO

Article history:
Received 27 July 2011
Received in revised form 25 January 2012
Accepted 26 January 2012

Keywords:
3D reconstruction
Medical imaging
Clinical routine
Automation
Similarity measures
DRR

ABSTRACT

Three-dimensional (3D) reconstruction of the skeleton from biplanar X-rays relies on scarce information digitalised by an operator on both frontal and lateral radiographs. In clinical routine, difficulties occur for non-skilled operators to discriminate the medial from the lateral femur condyle on the lateral view. Our study proposes an algorithm able to detect automatically a possible inversion of the two condyles by the operator at an early stage of the reconstruction process. It relies on the computation of two 3D femur surfaces, one directly from the operator digitalisation and the other from the same digitalisation with medial and lateral condyles automatically swapped. Pairs of virtual biplanar X-rays are computed for both reconstructions and the closest pair to the original X-rays is selected on the basis of similarity measures, pointing the correct 3D surface. The algorithm shows a success rate higher than 85% for both asymptomatic and pathological femurs whatever the initial condyle digitalisation of the operator, bringing automatically non-skilled operators acting in clinical routine to the level of skilled operators. This study validates moreover the proof-of-concept of automatic shape adjustments of a 3D surface on the basis of similarity measures in the process of 3D reconstruction from biplanar X-rays.

© 2012 IPEM. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Three-dimensional (3D) reconstruction from biplanar X-rays turned from research environment to clinical routine during the last decade [1]. The calibration of the system needs however to be known in order to infer the 3D from the planar images. This can be achieved either by performing the exam in calibrated systems [1], or by inferring the calibration by means of calibration objects [2] or as proposed more recently without calibration object [3], which allows the use of traditional radiograph systems. Once known the calibration, this technique allows personalised 3D reconstruction of the skeleton from a simple clinic exam such as radiography (e.g. [4,5]). This gives access to the clinician to a set of 3D information not available on planar images until now and constitutes a breakthrough for diagnosis and surgery planning (e.g. [6]). This technique appears thus very promising for further developments in clinical routine and a large amount of research is nowadays dedicated to 3D reconstruction from biplanar X-rays for the spine ([2,4,7]), the pelvis ([2]), the rib cage ([8,5]), the upper limbs ([9]) or the lower limb ([10,11]). In this framework, a new method for reconstructing the lower limb has been proposed recently by Chaibi et al. [12]. Among the parameters available to the clinician through this method, the femoral torsion (FT) parameter appears of major importance. This parameter measures the angle between the femoral neck axis (in the proximal femur) and the bicondylar femoral axis (in the distal femur) on an axial projection. The measure of this parameter, only available from 3D exams, is relevant in clinic for diagnosis and therapy of many disorders: femur malunion, rotation disorders during development (such as unstable patella), measure of anteversion of femur prosthesis (of possible major importance in unstable prosthesis), etc.

The precision of the reconstruction method relies on the few digitalisations required from the operator on the radiographs to initiate the process. In particular, the operator is instructed to superpose on the two radiographs two circles so that they fit at best the outlines of the two condyles of the distal femur. These two sets of stereo-corresponding circles will be used in the process to estimate the 3D position of the medial and lateral condyles, having therefore a major influence on the FT parameter. In order to distinguish the left femur condyles from the right femur condyles on the lateral radiographs, the left and right feet are shifted during the recording in the anterior–posterior direction, according to the shifted-feet protocol described by Chaibi et al. [12], as illustrated in Fig. 1. However, even in this position, Chaibi et al. report difficulties to discriminate the medial and lateral condyles on the lateral view (see Fig. 1). This difficulty leads sometimes the operator to locate on the lateral X-ray the medial condyle circle on the lateral condyle and vice versa. While experts and skilled operators rarely mix up the medial and lateral condyles (see [12]), the less trained end users in clinical routine report difficulties in such assessment

* Corresponding author.
E-mail address: Antoine.Serrurier@ensam.eu (A. Serrurier).

1350-4533/$ – see front matter © 2012 IPEM. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.medengphy.2012.01.008

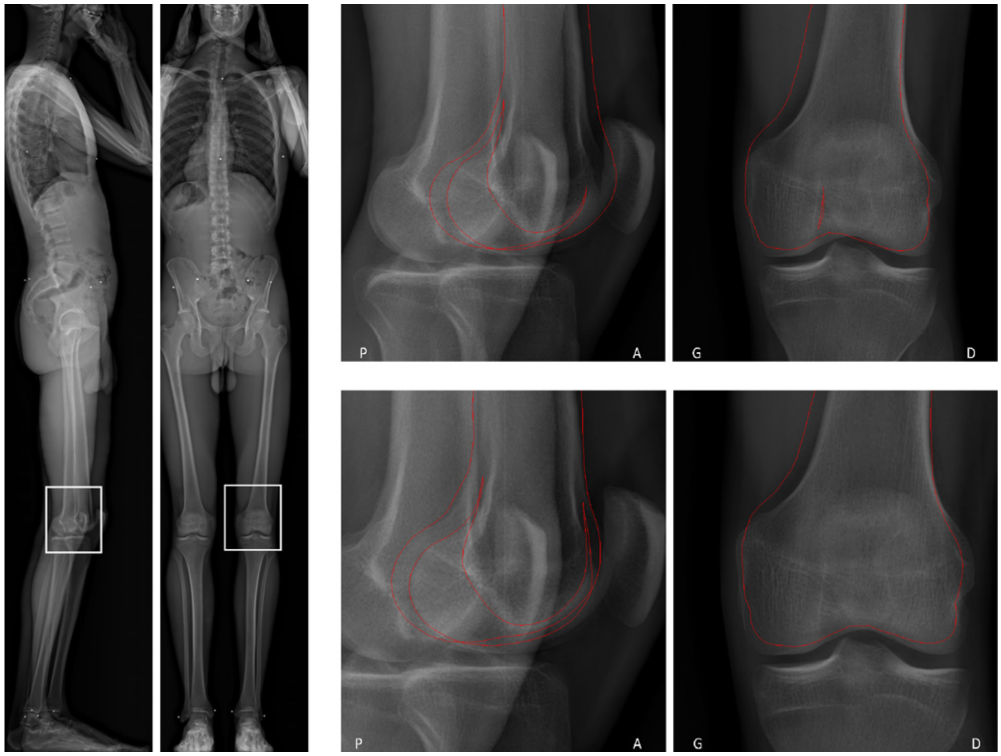

Fig. 1. Full body biplanar X-rays in shifted-feet position (left) and zooms on the right distal femur superimposed with the retroprojected femur contours for a correct condyle configuration (top right) and an inverse condyle configuration (bottom right); the femoral torsion absolute difference between the two reconstructions being 10.4°.

and are uncomfortable with the risk of inversion. This inversion leads in the 3D reconstruction to a surface whose medial condyle has the position of the lateral condyle in the anterior–posterior direction and vice versa. This latter configuration will be referred to in the article as *inverse condyle configuration*, as opposed to the *correct condyle configuration*. Inverse condyle configurations result in reconstructed femurs with twisted distal region, causing uncertainties in the calculation of the FT parameter, possibly wrong up to 30° or 40°. The inversion is hardly observable when the 3D surface is retroprojected on the X-rays as contours as they still conform to the two condyle outlines, as illustrated in Fig. 1. The correct condyle configuration detection relies thus on the skills of the operator and constitutes a real issue when used in wide clinical environment.

On the other hand, skilled operators in research environment appear able to discriminate correctly the medial and lateral condyles during the reconstruction process. We can therefore assume that the current process does not make the full advantage of the images. Our objective in this context is thus to develop a robust algorithm based on the image processing able to detect a possible condyle inversion directly after the operator has adjusted the condyle circles on the X-rays. This method aims to be automatic in order to decrease the dependence of the reconstruction process on the operator and to bring robustness for use in clinical routine.

The method proposed in this article is an enhancement of the 3D reconstructions detailed by Chaibi et al. [12] for the lower limb. It starts after the operator digitalisation and informs him at the end whether the condyle circles he digitalised on the X-rays are inversed or not. The 3D reconstruction used in this article is thus provided by [12] while the rest is developed on purpose for the algorithm. The algorithm is summarised as a flowchart in Fig. 2. The article is organised as follows: Section 2.1 describes the data used for the study, Sections 2.2–2.4 the main three steps of the algorithm, highlighted with a grey background on the flowchart of Fig. 2 and Section 2.5 the way to evaluate the algorithm. The results are presented in Section 3 and discussion in Section 4.

2. Materials and methods

2.1. Subjects and data

Two series of subjects have been considered for the study. The *asymptomatic group* gathered 20 volunteers, 16 males and 4 females, without known pathology of the lower limbs, with mean age of 35, ranging from 24 to 60. The *pathological group* gathered 10 patients, 7 males and 3 females, with mean age of 71, ranging from 62 to 84. The pathologies, representing a sample of the various possible femur pathologies, are summarised in Table 1. Two full body biplanar X-rays, with a resolution of 0.186 mm/pixel, were recorded by means of the imager EOS^{TM} at the Laboratory of Biomechanics (Paris, France) between February 2007 and September 2008

Table 1
Pathology classification for the 18 femurs of the pathological group. The arthritis grade is given on the Kellgren and Lawrence grading scale.

Femur number	Knee arthritis grade	Hip arthritis grade	Axis deformity
1	3	4	Varus
2	0	4	Varus
3	0	4	Normal
4	0	4	Normal
5	0	4	Normal
6	0	1	Normal
7	2	2	Normal
8	4	4	Varus
9	4	3	Varus
10	4	4	Varus
11	2	4	Varus
12	4	4	Varus
13	3	4	Varus
14	0	3	Normal
15	0	4	Normal
16	4	4	Valgus
17	4	4	Valgus
18	4	4	Varus

Download English Version:

https://daneshyari.com/en/article/876341

Download Persian Version:

https://daneshyari.com/article/876341

Daneshyari.com