The need to maintain the health of the musculoskeletal is crucial because this way we can prevent or solve deficiencies and anomalies of the human body activities.

To do so we need to use, find or develop new kinematic analysis systems like Vicon cameras, ToF cameras or in our case the Kinect cameras.

Comparing the Kinect camera point of view of accuracy, availability and price with others specialized motion capturing system we can conclude that the sensor in question is a very capable tool to study the kinematics of the human body in everyday activities or in sports with the aim to prevent or solve deficiencies of the musculoskeletal.

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UTILISATION DE CAPTEUR KINECT POUR ETUDIER LA CINEMATIQUE DU CORPS HUMAIN

Résumé:
Le corps humain est un mécanisme complexe qui se compose de multiples chaînes cinématiques. Le but de ces chaînes est de multitude maintenir le corps humain en mouvement continu nécessaire pour la vie quotidienne.
Dans cet article nous allons présenter un état de la technologie de pointe défini par son un énorme potentiel et de l'accessibilité pour étudier la cinématique du corps humain.
Notre travail étudie la façon dont le capteur Kinect est capable de prendre part à l'étude de la cinématique du corps humain.
***Mots-clés**: biomécanique, Kinect capteur, capteur de profondeur, la cinématique, le sport, le corps humain, le mouvement sans marqueurs*

ESTABLISHING THE 3D ACTIVE SPACE OF THE HUMAN UPPER LIMB USING AUTOLISP

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Abstract:
The paper presents a graphical method for determining the 3D active space of the human upper limb. The method is based on AutoLISP features and provides an accurate description of the active space. The main disadvantage is related to time computing which can be very large due to the amount of points describing the active space. We can also reveal the limitation of active space for persons having upper limb disabilities.
Keywords: *upper limb, 3D active space, AutoLISP*

INTRODUCTION

The human skeleton is not a perfectly rigid mechanical structure, articulated with idealized spherical or axial joints. In order to simplify the calculation routines, we assume that kinematic links are rigid bodies. Thus, some errors might occur in the kinematic analysis (Zhang, 2002) and in inverse dynamics as well (Risher et al., 1997).

It is well known that in time, most people lose a certain percentage of mobility of their joints. As a consequence, the active area of the upper limb is shrinking. This method provides the expression of the percentage of mobility loss for older persons or for disabled ones with respect to a normal person.

DESCRIPTION OF THE METHOD

For a complex kinematic study of the active space of the human upper limb, the considered open kinematic chain has 8 degrees of freedom, corresponding to the possibilities of motion allowed by each joint of the upper structure (Fig. 1). Thus, the 8 degrees of freedom are:
• 3 degrees of freedom for the shoulder;
• 2 degrees of freedom for elbow;
• 2 degrees of freedom for the wrist;
• 1 degree of freedom for joint metacarpophalanges.

- h = length of humerus;
- r = length of radius;
- p = length of carpian and metacarpian;
- d = cumulative length of phalanges.

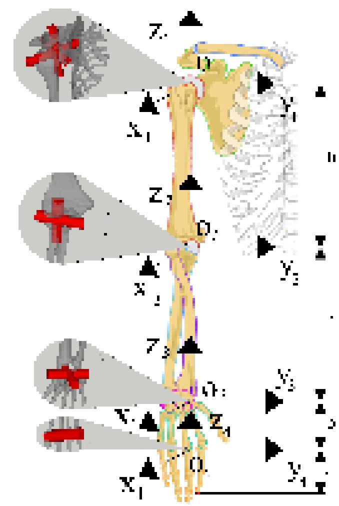

Fig. 1. Kinematic model of human upper limb

Table 1. Nominal values of joints variables

	θ_{1x}	θ_{1y}	θ_{1z}	θ_{2x}	θ_{2z}	θ_{3y}	θ_{3z}	θ_{4y}
Min	-45^0	0^0	-110^0	-45^0	-140^0	-90^0	-55^0	-45^0
Max	45^0	135^0	30^0	90^0	0^0	80^0	30^0	90^0

The general matrix G_{12} which represents the position and orientation of the reference system of phalanges with respect to the reference system considered fixed in the center of the shoulder joint, is determined as the product of transfer matrices:

$$G_{12} = {}^0T_1 \cdot {}^1T_2 \cdot {}^2T_3 \cdot {}^3T_4 \cdot {}^4T_5 \cdot {}^4T_6 \cdot {}^6T_7 \cdot {}^7T_8 \quad (1)$$

Thus, the general form of G_{12} matrix is :

$$G_{12} = \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (2)$$

PRACTICAL APLICATION

Based on the kinematic model and on the anatomic considerations above, we have established the active area of the human upper limb using a graphical representation of successive positions.

The limits and the configuration of the active space limits of the human upper limbs are important for designing the ergonomic issues surrounding people with disabilities (workspace, living space). Compared with analytical methods, this graphical method provides both visual and indicative expressions of the accurate active area of the human upper limb.

Generating points

We have created a computer routine dedicated to this purpose, using the AutoLISP programming language based on :

- 8 "while" loops, one for each joint of the considered kinematic chain;
- 4 travel units, one for each joint of the upper limb;
- a drawing unit for the mobile point;
- an extraction unit.

The 8 "while" loops are subordinated one to the other, as shown in the logical scheme (Fig. 2). The "while" loop corresponding to the joint variable θ_{4y}, the program draws the points one by one and their coordinates are extracted for each increasing increment of the variable, as long as the condition $\theta_{4y} < \theta_{4y\ max}$ is met.

For the loop θ_{3y}, the variable angle will increase incrementally from minimum to maximum. So, for each increment of its own the subordinate loop, loop θ_{4y}, will perform a complete cycle of drawing points as described in the previous paragraph. When the maximum condition is met, i.e. $\theta_{4y} = \theta_{4y\ max}$, for the master loop, the variable in the loop θ_{3x}, increases one by one step, then the drawing cycle resumes from the loop θ_{3y}.

The loops of the variables joint θ_{3x}, θ_{2z}, θ_{2y}, θ_{1z} and θ_{1y} have the same behavior as θ_{3y} loop. For the most part, the θ_{1x} loop has a similar behavior to the other loops, the difference being, as shown in the logical scheme (Fig. 2), that when the condition of maximum is met, the program ends.

The movement unit is a group of commands that perform the displacement of the active coordinate system from one joint to another. The displacement distances are the lengths of bone segments that form the skeleton of the upper limb (humerus, radius, carps + metacarps, phalanges). At one point only one of the eight coordinate systems is active, i.e. the coordinate system corresponding to the loop in progress.

The drawing unit is a collection of commands that perform mobile point drawing. The mobile point is a point on the distal extremity of phalanx of the forefinger (index).

The extraction unit, so called "extraction subroutine", enrolls in a TXT file the cartesian coordinates of the mobile point with respect to the fixed coordinate system (WCS). The world coordinate system (WCS) site can be located anywhere in space, but in this case is situated in the center of the scapular-humeral joint.

Fig. 2. Logical scheme

The total number of points (n) achieved after running the program is the product of the number of points corresponding to each joint variable (i_{uv}).

$$n = i_{1x} \cdot i_{1y} \cdot i_{1z} \cdot i_{2y} \cdot i_{2z} \cdot i_{3x} \cdot i_{3y} \cdot i_{4y} \qquad (3)$$

where: $i_{uv} = \dfrac{\varphi_{uv}}{p_{uv}}$ and $i \in N$, u=(1,2,3,4), v=(x,y,z) (4)

φ_{uv} - the definition domain of variable angle *uv*

$$\varphi_{uv} = \left|\theta_{uv\min}\right| + \theta_{uv\max} \qquad (5)$$

p_{uv} – the incremental step of angular variable uv.

The graphical representation of the active space of the human upper limb was performed considering that all kinematic joints perform simultaneous movements, within the limits of joint configurations.

Due to the complexity of the model, each of the eight areas that define the angular variables is divided into four intervals. By running the AutoLISP program, we get a total of 390625 points (Fig. 3), in the current AutoCAD file.

CONCLUSIONS

This method provides both quantitative information by viewing the point cloud that describes the 3D space of the human upper limb, as well as qualitative information, because we can read the accurate Cartesian coordinates of the points that form this space.

The method becomes more difficult to compute as the incremental values of joint variables increase, as the computing time is longer. This shortcoming can be removed by using a computing machine with a high frequency processor.

Compared with the analytical method, the method of drawing the successive positions is easier to use due to the graphic facilities provided by AutoLISP programming environment.

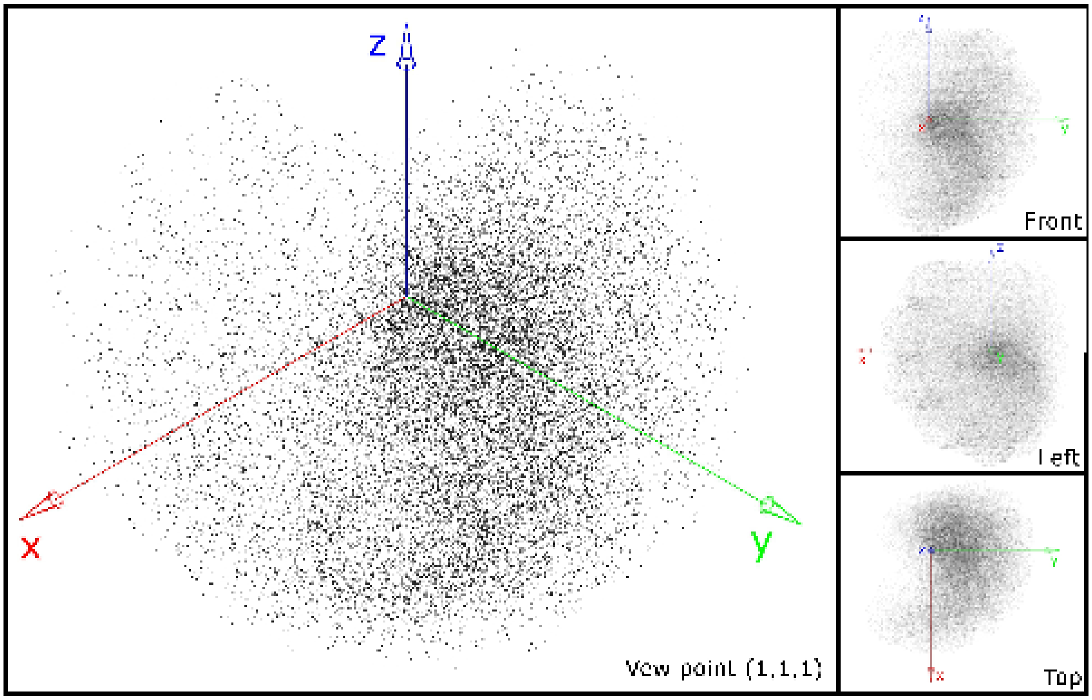

Fig. 3. Active space of human upper limb

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Établir l'espace 3D active du membre supérieur humain à l'aide d'AutoLISP

Résumé:
Cet article présente une méthode graphique pour déterminer l'espace 3D active du membre supérieur humain. La méthode est basée sur les fonctionnalités par AutoLISP et fournit la description précise de l'espace actif. Le principal inconvénient est lié au temps de calcul, qui peut être très grande en raison de la quantité de points qui décrie l'espace actif. Nous pouvons aussi révéler la limitation de l'espace 3D actif pour les personnes ayant une déficience des membres supérieurs.

Mots-clés: *membre supérieur, actif espace 3D, AutoLISP.*