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Model-based reconstruction of 3D human arm motion from a monocular image sequence

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Abstract

In this paper we propose a model-based approach of human arm motion reconstruction from monocular image sequence. The approach is based on the assumption that the human arm can be considered as an articulated object with a known kinematic structure. We introduce the kinematic model of the human arm, define the reconstruction process and show some preliminary results.

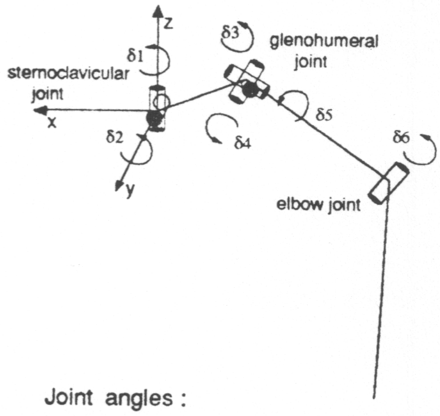
1 Introduction

A traditional approach to reconstruct human body motion in 3D space is to reconstruct the movement of special markers attached to the human body [1,3, 6]. The 3D coordinates of the markers are computed by triangulation, using two or three cameras. The human arm, as a part of the human body, can be modeled as an articulated object consisting of three rigid segments connected by joints. The segments correspond to real body parts: the upper arm, the forearm and the palm.

In this paper we will try to show that when the lengths of the arm segments and the mechanism of joint-joint displacement are known, the human arm motion in 3D space can be reconstructed from the orthographic projection of the joint points on the image plane. To address the multiple solution problem we assume that the starting position of the arm motion sequence is known and that the motion is smooth.

In the next section we introduce a kinematic model of the human arm. In the third section we formulate the relation of the kinematic model to its projection on the image. In the fourth section we show an example of a reconstructed human arm motion from real images. At the end, we give directions for further work.

2 Kinematic model of the human arm



Joint angles :

$\delta 1$ – clavicular flection/extension
$\delta 2$ – clavicular abduction/adduction
$\delta 3$ – humeral flection/extension
$\delta 4$ – humeral abduction/adduction
$\delta 5$ – humeral rotation
$\delta 6$ – elbow flection/extension

Limits of joint angle values :

$\delta 1 = [-17^\circ, 17^\circ]$
$\delta 2 = [-6^\circ, 20^\circ]$
$\delta 3 = [-9^\circ, 160^\circ]$
$\delta 4 = [-43^\circ + \delta 3/3, 153^\circ - \delta 3/6]$
$\delta 5 = [-90^\circ + 7\,\delta 3/9 - \delta 4/9 + 2\,\delta 3\,\delta 4/810,$
$60^\circ + 4\,\delta 3/9 + 5\,\delta 3\,\delta 4/810]$
$\delta 6 = [-90^\circ, 60^\circ]$

Figure 1: Kinematic model of the left arm.

The knowledge about joint positions, segment lengths, ranges of angle values and dependencies among some joint angles δ_i (see Fig. 1) can be synthe

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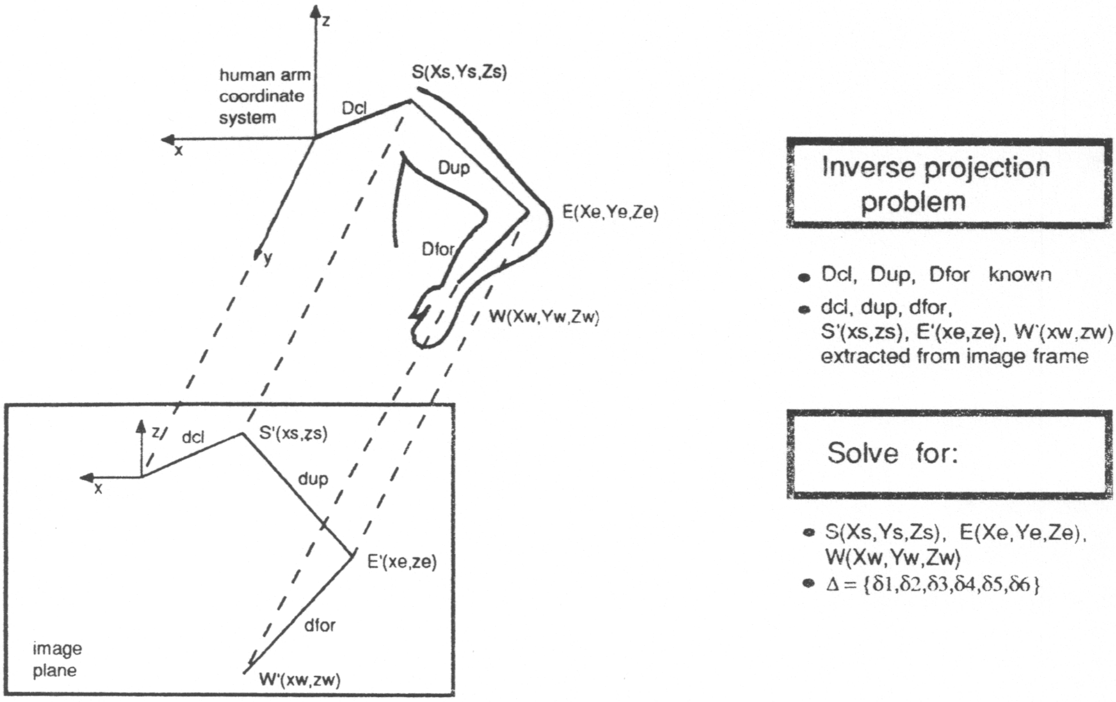

Figure 2: Relating the 3D model to its 2D projection.

sized as a **kinematic**[1] **model of the human arm** [4,7]. According to this model, the arm (without the palm) has six revolute degrees of freedom (DOF). The root coordinate system is placed in the sternoclavicular joint. We will use the kinematic model to constrain the process of recovery of the 3D motion from 2D image data. On one hand, the limitations and dependances among joint angles can be used to reject the unplausible solutions. On other hand, predictions about joint positions in following frames can be made.

3 Image projection geometry

The mathematics of image projection depends on the camera model that is used. We assume that the projection is orthographic (see Fig. 2). The inverse projection problem can be defined as follows: **from a single orthographic view of the joint points of the arm find a unique solution for the positions of the joint points in space**. The position of the joint points in space can additionaly be described by the kinematic vector $\Delta = \{\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6\}$.

4 Experimental results

Here is an example of a reconstruction of 3D motion of the human arm from a sequence of real images. The shoulder joint point is kept at the same position all the time. The image sequence was taken under orthographic projection with the camera placed in front of the human body [5]. The locations of joint points in each frame was in this experiment indicated manually (see Fig. 3.a).

First, the 3D positions of the joint points are calculated using the algebraic constraints of the kinematic model (see Fig. 3.b). Next, the 3D trajectories of the joint points are derived from transition between two subsequent images (see Fig. 3.c). The corect solution for the elbow joint point trajectory is chosen using the start position of the arm. The corect solution for the wrist joint point trajectory is chosen by projecting the recovered motion back to the image plane. At the end, the overall reconstructed motion is described with the time-varying joint ange values δ_i of the kinematic model (see Fig. 3.d).

5 Conclusion and further work

Under the assumptions that:

- the human arm motion can be described with the kinematic model developed by Lenarčič [4] and Umek [7],

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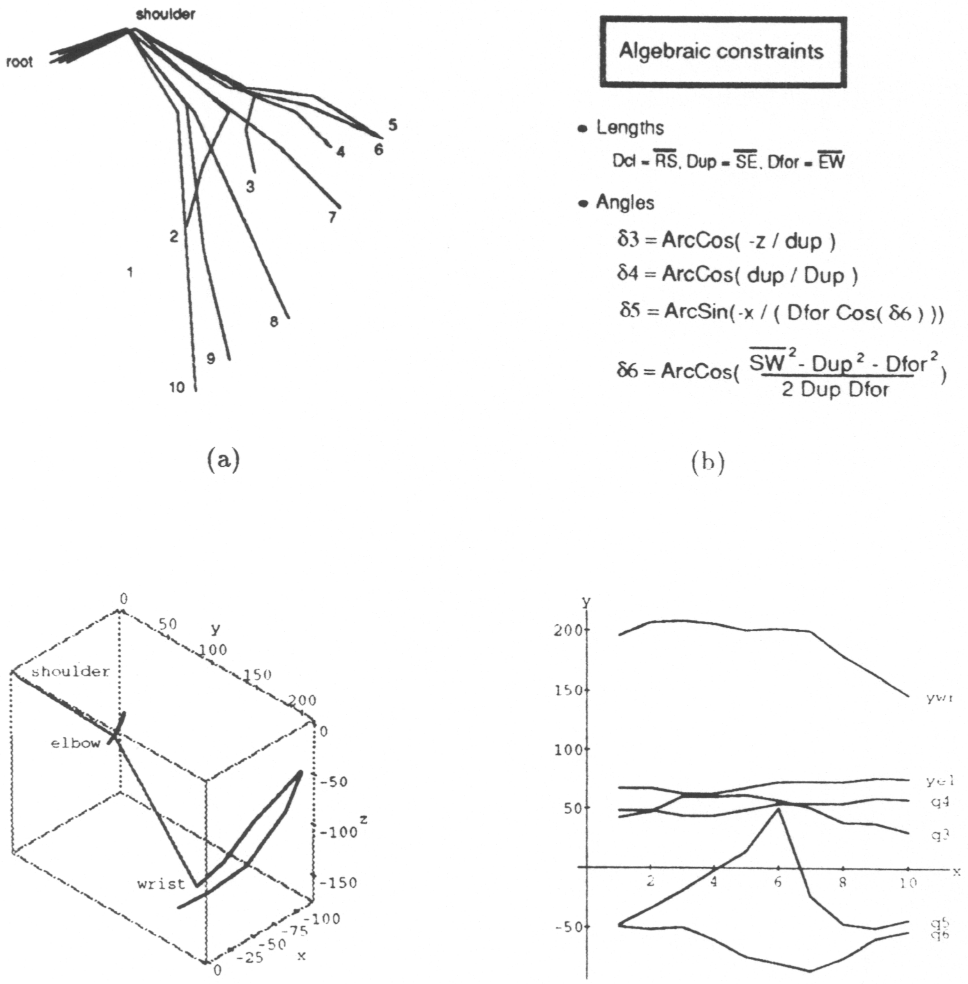
[1] **Kinematics** deals with the geometry of motion with respect to a fixed coordinate frame as a function of time, regardless of the forces and moments that cause the motion.



(a) (b)

(c) (d)

Figure 3: Experimental results: (a) projections of the joint points into the image plane, (b) algebraic constraints of projection, (c) reconstructed trajectories of the elbow and wrist joint point, (d) the time-varying joint angles as functions of time.

- the 2D position of the joint points can be extracted from each image frame and

- the motion is smooth and the start position of the arm is known,

we developed a software package for reconstructing 3D human arm motion from monocular image sequence. The software is written in *Mathematica 1.2* programming language and is limited to reconstruction of movements of the left arm from image sequences taken with camera in front of the body. We tested the package on many sequences and one of them is presented in this paper.

The further work would include integration of this software with a software for extraction the joint points from image frame [2] into a system for automatic reconstruction of the human arm motion.

Acknowledgement

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References

[1] C. I. Attwood, G. D. Sullivan, K. D. Baker, "Model-based recognition of human posture using single synthetic images", In *Proceedings of the 5th Alvey Vision Conference*, 1989.

[2] V. Filova, "Software package for modeling 2D image data", IJS Technical report DP - 6735, Jožef Stefan Institute, Ljubljana, Slovenia, 1992

[3] A. Koutamanis, V. Mittosi, "On the recognition of posture", In *Proceedings of the 11th Internacional Conference on Pattern Recognition*, Hague, 1992

[4] J. Lenarčič, A. Umek, "Experimental evaluation of human arm kinematics", In *Proceedings of the 2nd International Symposium on Experimental Robotics*, Toulose, France, 1991.

[5] M. Leonardi, Instalation of ANVAM image processing system, IJS Technical report DP - 6716, Jožef Stefan Institute, Ljubljana, Slovenia, 1993

[6] R. J. Qian, T. S. Huang, "Motion analysis of human ambulatory pattern", In *Proceedings of the 11th International Conference on Pattern Recognition*, Hague, 1992

[7] A. Umek, "Kinematic analysis of human arm and evaluation of the workspace using computer graphics", Master Thesis, University of Ljubljana, Slovenia, 1992