Vehicle Occupant Posture Analysis Using Voxel Data

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Abstract

Analysis of the vehicle occupant posture is a key problem in designing "smart airbag" systems. Vision based technology could enable the use of precise information about the occupant's size, position, and posture in making airbag deployment decisions. In this paper, we present our experiments in estimation of the body posture of a sitting person using a motion capture system that performs analysis of voxel data. We will show that this system is capable of extracting posture of the body and the head with good accuracy.

1. Introduction

Analysis of the vehicle occupant posture is a key problem in designing "smart airbag" systems. A new law, which will go into effect in 2004 in the USA requires the airbag systems to be able to distinguish small persons and persons not being in a safe position for airbag deployment [1]. One of the main difficulties encountered by the decision logic systems used in airbag deployment deals with the critical assumption about the occupant size and position in the car at the time of a crash. Most airbags consider a single standard for the occupant's size and the nature of the crash. Vision based technology could enable the use of precise information about the occupant's size, position, and posture.

In recent years, first efforts in building vision based seat occupation detection have been made [2, 3, 4]. However, these systems extract only limited information. In [2], only three categories of seat occupancy are recognized: empty seat, occupied seat and infant in the seat. Body size and pose are not estimated. In [3, 4] only passenger's head position is estimated using a stereo system.

In this paper, we present our experiments in estimation of the body posture of a sitting person using a novel motion capture system that performs analysis of voxel data [5]. We will show that this system is capable of extracting posture of the body and the head with good accuracy.

2. The multi-camera motion capture system

We have developed a fully automated motion capture system [5] that uses the input from multiple cameras (Figure 2). Foreground silhouettes from the input images are used to compute a 3D voxel reconstruction of the human body at each frame. The system performs the automatic model acquisition and tracking.

Voxel reconstruction of the human body shape is computed by checking for each of the voxels in the volume of interest if it projects to a foreground, body pixel in each of the image planes.

The automatic model acquisition consists of two parts. First, initial estimates of body part sizes and locations are found using a heuristic procedure that uses the knowledge of the average shapes and sizes of the parts. Then, these estimates are refined using a Bayesian network that imposes the known proportions of the human body.

The body model we use is shown in Figure 1. Each axis of rotation in different joints is modeled using the twists formulation. By imposing the limits on the joint angles, such model is guaranteed to be in a physically valid configuration.

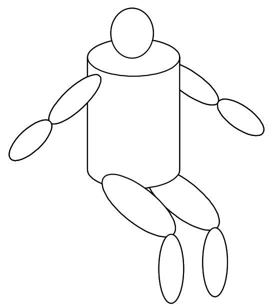

Figure 1 The human body model

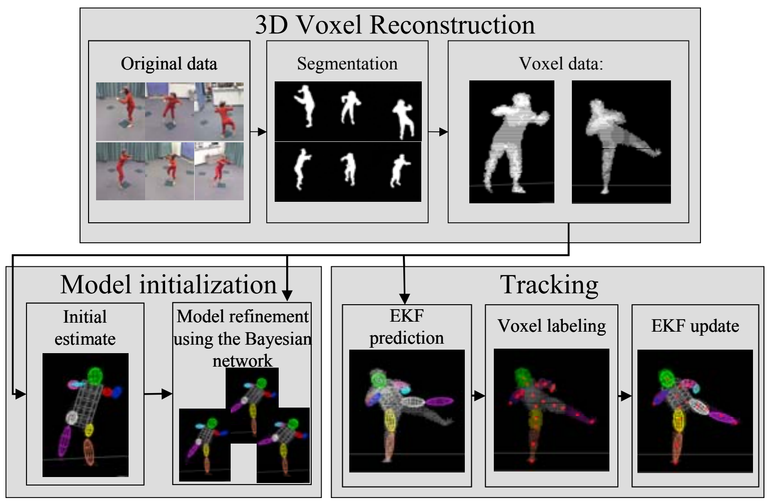

Figure 2 Motion capture system flowchart

For the measurements, we chose a set of points on the human body that are either centroids or endpoints of different body parts. The twists framework for describing the joint rotations leads to a simple formulation of the Kalman filter tracker, which adjusts the model position and configuration to the measurements in each new frame. To find the locations of measurement points in each new frame, the voxel data is labeled using the model position and configuration prediction from the previous frame. The voxel labeling algorithm takes the advantage of the fact that the voxel reconstruction is of the dimensions of the real person, and uses the known sizes and shapes of body parts to locate them even for large frame to frame displacements.

3. Results

We have applied the described algorithm to several sequences involving sitting people who perform head and torso tilting to simulate the body movements inside a car. The body part sizes extracted using this system were used for VRML modeling of the vehicle as shown in Figure 3. Body part sizes are given in Table 1.

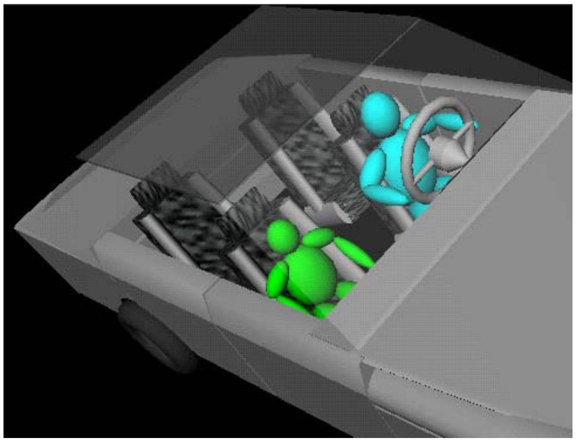

Figure 3 VRML model of the car. The models of the occupants were built with body part sizes extracted from the real data using our motion capture system

	Average volume		Torso	Head	Upper arm	Lower arm	Thigh	Calf
	voxels	cm^3	dim *x*/*y*/*z* [mm]	dim *x*/*y*/*z* [mm]	dim *x*/*y*/*z* [mm]	dim *x*/*y*/*z* [mm]	dim *x*/*y*/*z* [mm]	dim *x*/*y*/*z* [mm]
Adult	7740.8	120949.7	138.146 143.283 275.999	98.31 113.63 120.216	50.5998 50.5998 151.8	59.7998 59.7998 179.399	78.1998 78.1998 234.599	87.3997 87.3997 262.199
Child	3891.5	60804.8	109.109 139.361 179.608	68.7532 80.7406 91.7084	49.3922 49.3922 98.7844	38.4874 38.4874 134.706	64.6589 64.6589 161.647	51.3166 51.3166 179.608

Table 1 Average volume and body part sizes extracted from the sequences containing a sitting adult and a child

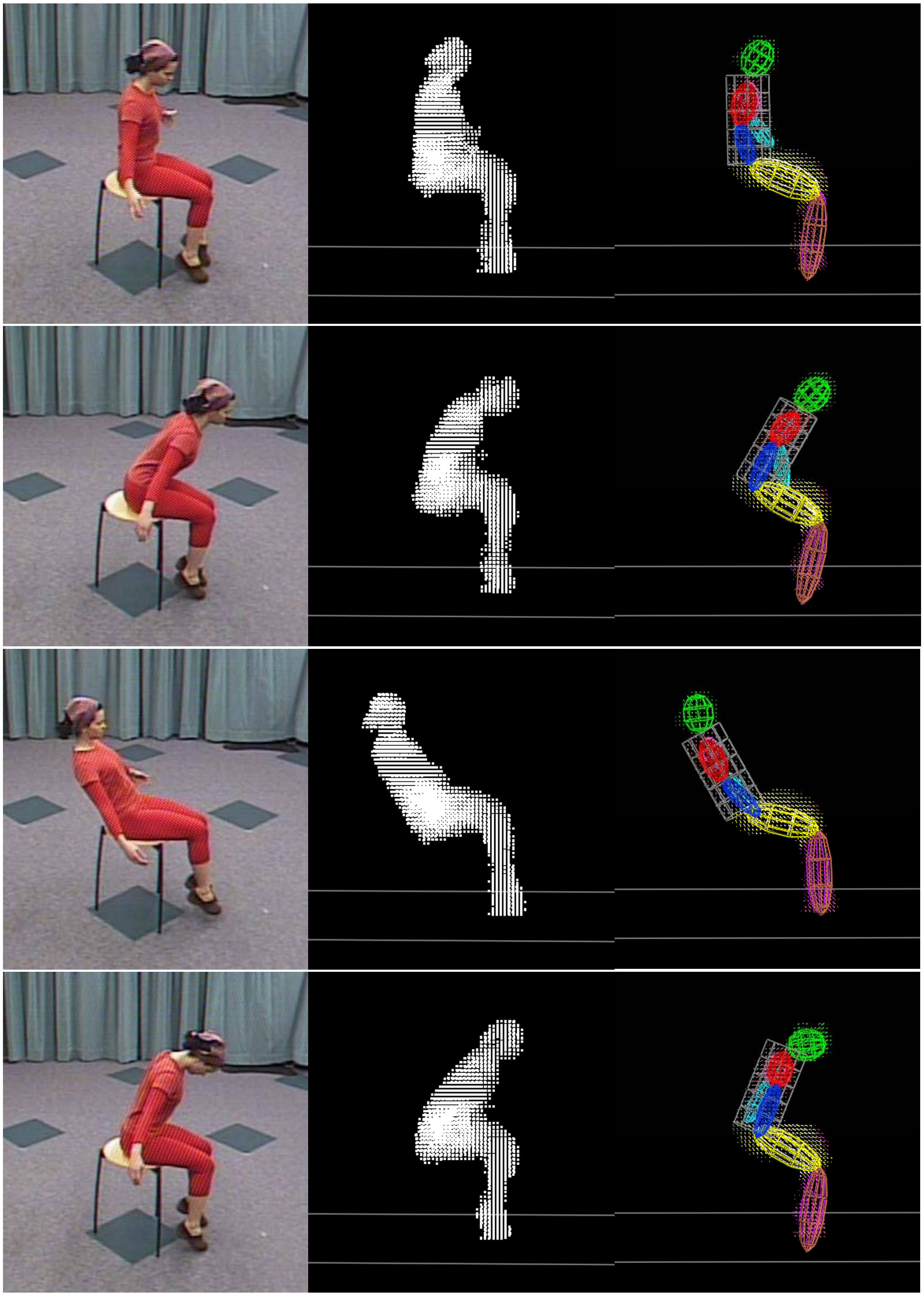

Figure 4. Sample frames for the sequence of a sitting person. Left: original data; Middle: voxel reconstruction; Right: tracking result

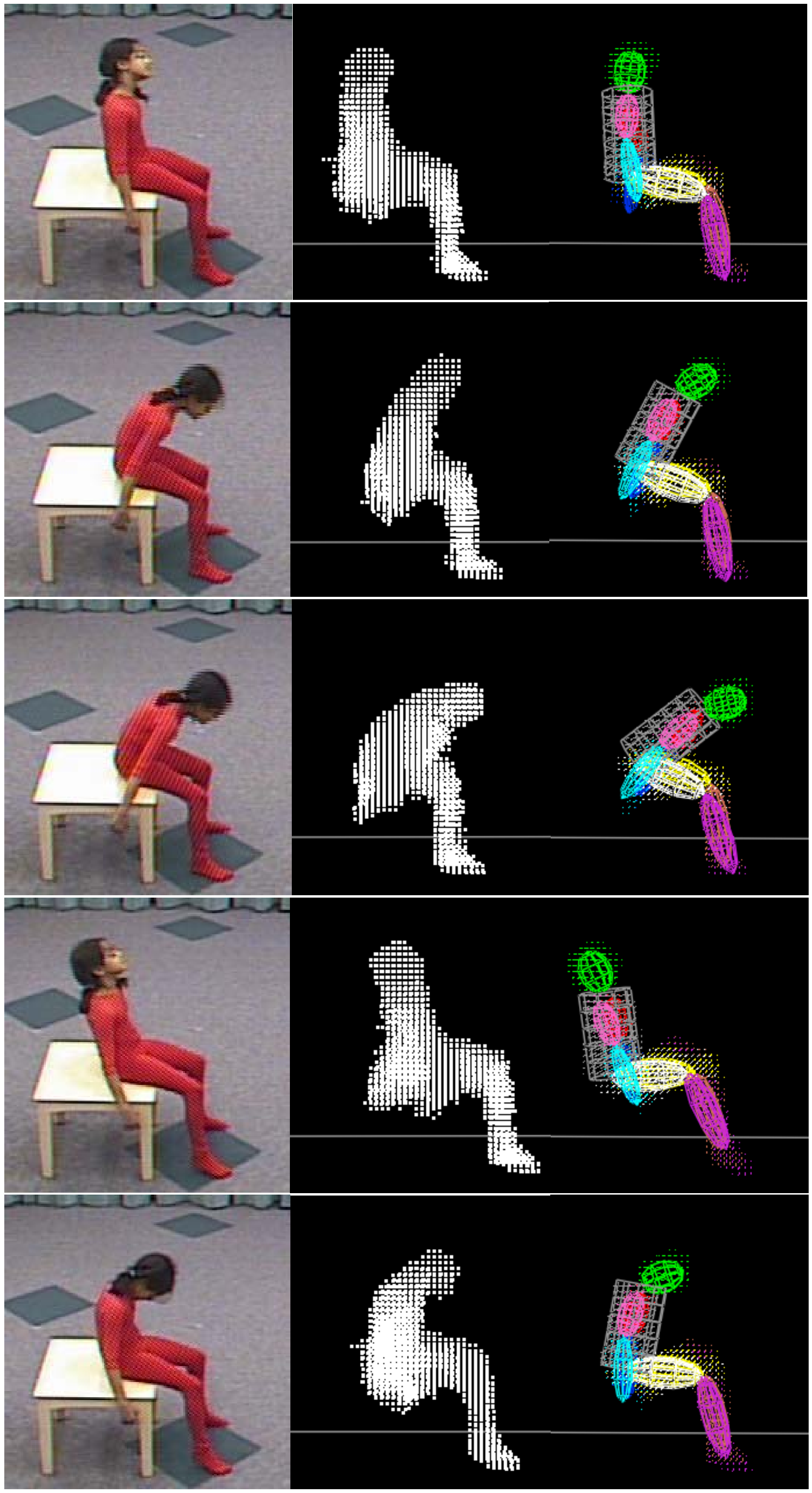

Figure 5 Sample frames for the sequence of a sitting child. Left: original data; Middle: voxel reconstruction; Right: tracking result

Figure 4 shows sample frames for the sitting adult sequence and Figure 5 shows sample frames for a sequence that involves a nine-year-old child. Figure 6 shows some key joint angles and Figure 7 shows the torso centroid coordinates for the sequence with the adult.

The key features of the performed motion are clearly visible. The knees are kept bent at a constant angle, hip angles agree with the torso tilting forward and backward and the neck angle with the head tilting backward and forward. The coordinates of the torso centroid match the same torso tilting motion.

The analysis of the results reveals very good capture of the important quantities, such as the hip angle, torso centroid and neck angle.

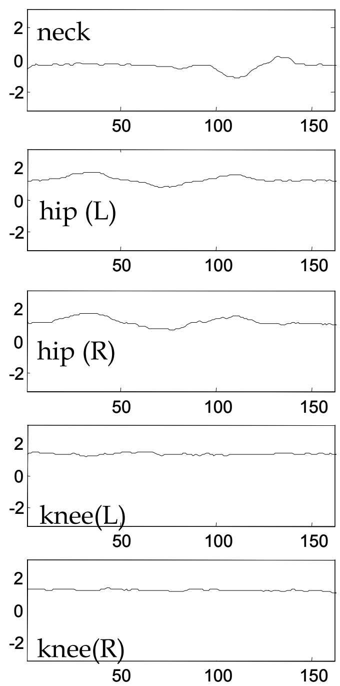

Figure 6 Some joint angles as functions of time for the sequence containing a sitting person. *x*-axis: frame number, *y*-axis: radians

4. Discussion

In this paper, we have demonstrated that a voxel-based motion capture system can successfully extract the posture of a sitting person. Important details such as the head and torso position and orientation are extracted accurately.

However, the conditions under which these experiments were conducted were idealistic in several aspects compared to the real conditions inside a car. First, there was little occlusion of the person's body in the camera views. The only occlusion was caused by the chair in one of the camera views, but the legs were clearly visible by other cameras. Second, the current system takes approximately 20 seconds to compute the voxel reconstruction and the tracking result, which is far from the necessary real-time performance of the "smart airbag" system. However, in implementing this system, speed was not of great concern and many improvements could be made to improve it. Finally, to successfully deploy an airbag, a classification system is needed that makes a decision on the type of posture the person is in. This task requires detailed knowledge of the airbag operation parameters and with previously mentioned tasks is left for future research.

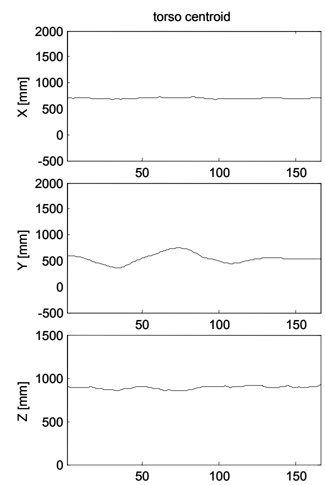

Figure 7 Torso centroid as a function of time for the sequence containing a sitting person

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