THE MS KINECT USE FOR 3D MODELLING AND GAIT ANALYSIS IN THE MATLAB ENVIRONMENT

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Abstract

The three-dimensional modelling presents a very important tool for analysis of the movement both in medicine and engineering. While video sequences acquired by a complex camera system enable a very precise data analysis it is possible to use much more simple technical devices to analyse video frames with the sufficient accuracy. The use of MS Kinect allows a simple 3-D modelling using image and depth sensors for data acquisition with the precision of 4-40 mm depending upon the distance from the sensor. The matrix of 640 x 480 pixels can be then used for the spatial modelling of a moving body. The goal of the paper is to present (i) the use of MS Kinect for data acquisition, (ii) data processing in the MATLAB environment, and (iii) application of the 3D skeleton model in biomedicine.

1 Introduction

The three-dimensional data acquisition forms a very important research area related to space modelling with many applications in engineering and biomedicine. While synchronized camera systems [3, 12, 10] allow precise but also expensive technical solution it is possible to use much less expensive systems based upon application of the depth sensors use. The MS Kinect allows to acquire such data sets and their processing in the mathematical environment of MATLAB to enable movement analysis, gesture recognition and robotic systems control [16, 15, 4, 6].

This paper is devoted to the use of the MS Kinect system for the gait data acquisition, for analysis of movement [1, 9, 5] and gait disorders including the study of the Parkinson's disease. Selected mathematical methods are applied for the motion tracking and classification of observed sets of individuals.

2 Methods

2.1 Data Acquisition

Fig. 1 summarizes the principle used for the gait analysis of a selected frame. Fig. 1(a) presents location of MS Kinect sensors used to record separate image frames. The depth sensor consists of an infrared projector (on the left) and an infrared camera (on the right) that uses the structured light principle [17, 11] allowing the detection of the distance of object components.

The latest image acquisition [7, 14] toolbox includes tools for the direct interconnection of the MS Kinect and Matlab environment for processing of data acquired using standard tools used for hardware devices connected to PC through the USB. The IMAQHWINFO provides the following information:

```
1      >> h=imaqhwinfo('kinect',1)
2
3              DefaultFormat: 'RGB_640x480'
4        DeviceFileSupported: 0
5                 DeviceName: 'Kinect Color Sensor'
6                   DeviceID: 1
7      VideoInputConstructor: 'videoinput('kinect', 1)'
8     VideoDeviceConstructor: 'imaq.VideoDevice('kinect', 1)'
9           SupportedFormats: {1x4 cell}
```

```
10
11     >> h=imaqhwinfo('kinect',2)
12
13              DefaultFormat: 'Depth_640x480'
14        DeviceFileSupported: 0
15                 DeviceName: 'Kinect Depth Sensor'
16                   DeviceID: 2
17     VideoInputConstructor: 'videoinput('kinect', 2)'
18    VideoDeviceConstructor: 'imaq.VideoDevice('kinect', 2)'
19           SupportedFormats: {1x3 cell}
```

Both the RGB camera and the depth sensors store information in matrices of size 640x480. The guaranteed and verified accuracy of the depth sensor is changing from 4 mm to approximately 40 mm, depending on the distance from the sensor [2, 8, 13].

Data of the *Videoinput* class can be further followed and separate snapshots obtained and visualized by the following commands:

```
1     % Image Sensor Data Acquisition
2       imageVid = videoinput('kinect',1);
3         preview(imageVid);
4         depthMap = getsnapshot(imageVid);
5           imshow(imageMap)
6           stoppreview(imagehVid)
7     % Depth Sensor Data Acquisition
8       depthVid = videoinput('kinect',2);
9         preview(depthVid);
10        depthMap = getsnapshot(depthVid);
11          imshow(depthMap)
12          stoppreview(depthVid)
```

Matrices of image data and depth sensor data can be further processed. A special interest should be given to the *DepthMap* matrix containing information of the depth sensor associated with each image element. Fig. 1(c) presents a selected image sensor frame while Fig. 2 shows the difference of subsequent image frames to reject static parts of the scene observed. It is necessary to have in mind that this difference is zero for static parts but with errors given by the accuracy of Kinect sensors. Fig. 2(c) presents this difference for a selected scene area and image data. Similar analysis prove the assumed accuracy of the depth sensor as well.
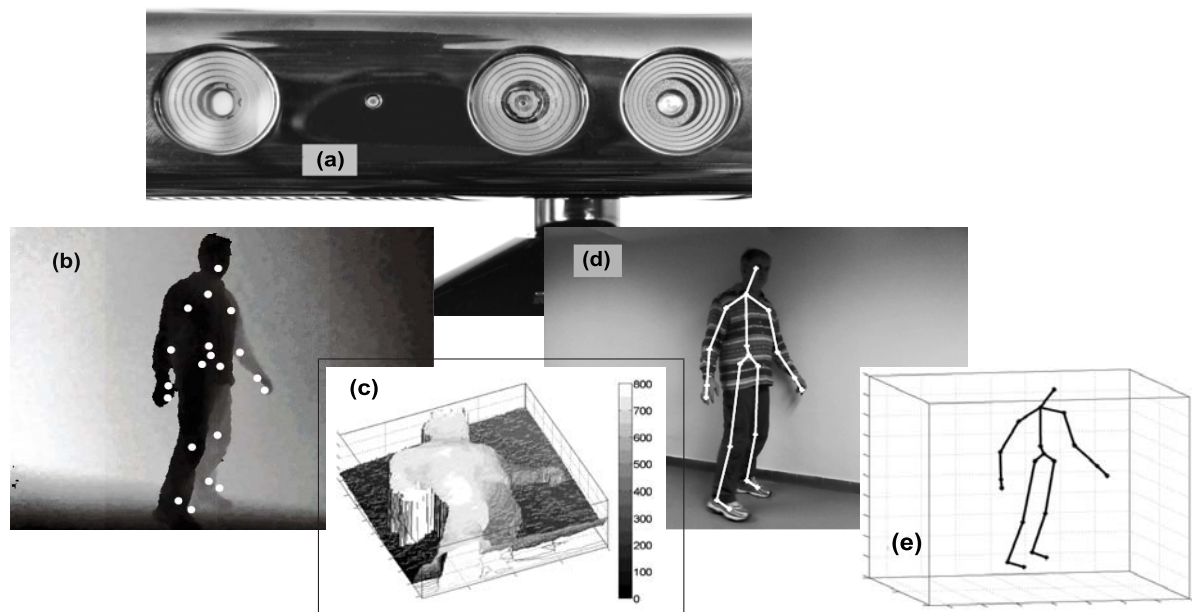

Figure 1: MS Kinect use for 3D modelling presenting (a) MS Kinect sensors, (b), (c) the depth sensor map, (d) selected RGB camera frame, and (e) the 3D skeleton model in MATLAB
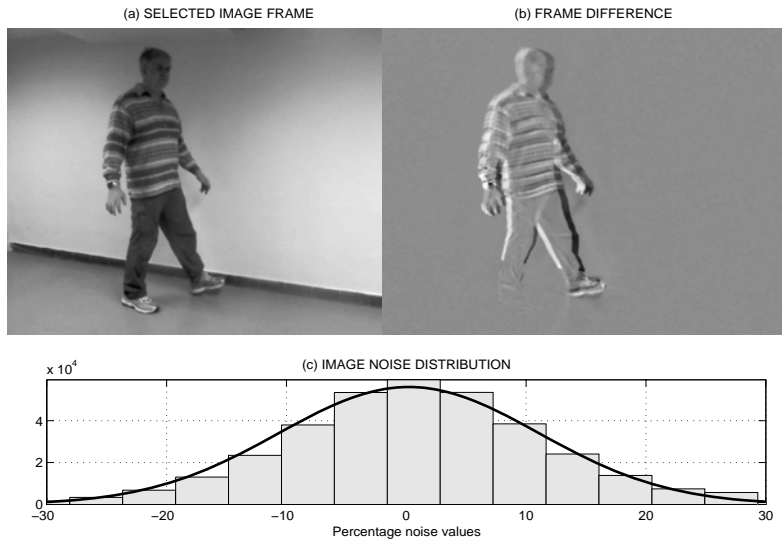
Figure 2: MS Kinect data analysis presenting (a) the selected frame acquired by the image sensor, (b) the difference of selected subsequent image frames, and (c) the distribution of image noise in the selected static region

2.2 Skeleton Tracking

The skeleton tracking algorithm process these data to provide information about the location of the joints specified in Fig. 1(c) using joint numbering and the connection map presented in Table 1.

Table 1: SKELETON POSITIONS AND CONNECTION MAP OF VIDEO RECORDS

Skeleton Positions				Connection Map		
Joint	No.	Joint	No.	Part	Connection Vectors	
hip center	1	wrist right	11	spine	[1 2],[2 3],[3 4]	
spine	2	hand right	12			
shoulder center	3	hip left	13	left hand	[3 5],[5 6],[6 7],[7 8]	
head	4	knee left	14			
shoulder left	5	angle left	15	right hand	[3 9],[9 10],[10 11],	
elbow left	6	foot left	16		[11 12]	
wrist left	7	hip right	17	right leg	[1 17],[17 18],[18 19],	
hand left	8	knee right	18		[19 20]	
shoulder right	9	ankle right	19	left leg	[1 13],[13 14],[14 15],	
elbow right	10	foot right	20		[15 16]	

Data analysis is based upon the detection of image components. While it is possible to propose own algorithms we used the standard method for detection of joints and the skeleton tracking in M cycles by the following commands:

```
1       start(depthVid); start(colorVid);
2       for i=1:M
3         trigger(depthVid); trigger(colorVid);
4           image = getdata(colorVid);
5           [depthMap,~,depthMetaData] = getdata(depthVid);
6         skeletonJoints = ...
7           depthMetaData.JointImageIndices(:,:,depthMetaData.IsSkeletonTracked);
8         R{i}=skeletonJoints;
9       end
```

Information saved in the cell variable R is then used for further data analysis.

3 Results

Skeleton data acquired by the MS Kinect system were further used for gait analysis with the sampling rate of 30 frames per second. Signal processing included digital data filtering to reduce observation errors using the evolution of mass centers presented in Fig. 3 for a selected individual and chosen central joints 1-3. Fig. 4 presents the time evolution of centers of mass of the right leg (19-20) and left leg (15-16) allowing the evolution of their distance with respect to the walk length. The stride length was then evaluated using maxima of distances between legs.
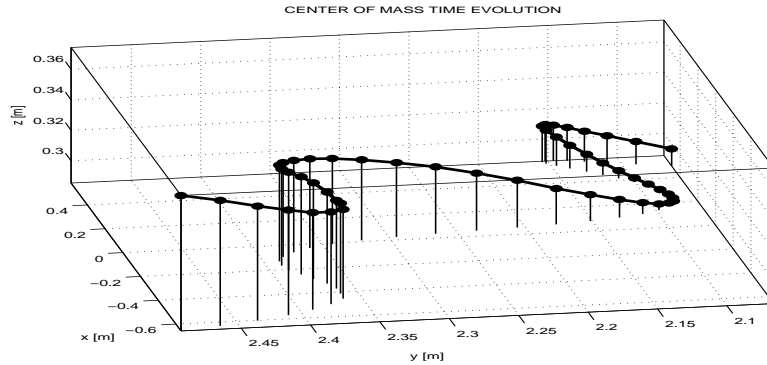

Figure 3: The evolution of the mass center evaluated for selected joints during a walk of a chosen individual
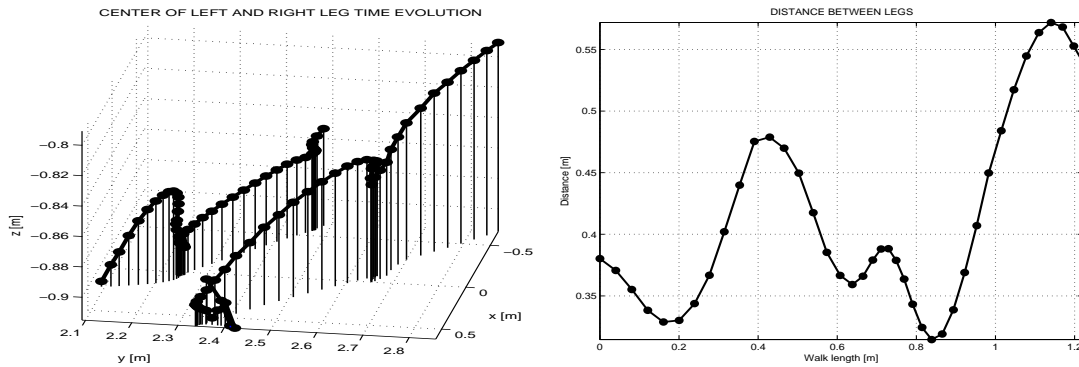

Figure 4: The evolution of the mass centers of individual legs and their distance used for the stride length evaluation

The experimental part of the study was devoted to the gait analysis of two sets of individuals observed in the Movement Disorders Center of the Faculty Hospital in Hradec Králové. The first set included 20 patients with the Parkinson's disease (PD) and the second set of 20 healthy age-matched individuals. The MS Kinect was installed about 60 cm above the floor to record the straight walk of each individual. The walk was approximately 4 m long repeated 5 times. A special attention was paid to the removal of gross errors during turns of individuals. Results proved the substantial difference between the average stride length of individuals with the Parkinson's disease and that of age-matched control.

4 Conclusion

Results obtained confirm that the MS Kinect device can be used for gait analysis with the sufficient accuracy and it can replace expensive camera systems in many cases. But it is necessary to choose the appropriate mathematical processing methods to reduce errors of the image and depth sensors. Further analysis will be devoted to more accurate joints detection as well.

Acknowledgments

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