Objective Assessment of Patients with Parkinson's Disease

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Abstract: - The camera system is described for hand movement analysis in Parkinson's disease. Since lesions in different structures of the central and peripheral nervous systems cause specific disturbances of hand motor function we measure the hand motion trajectory. The patients perform a natural manual transport task (moving an object from one place to another) repeatedly in OFF and ON medicated status and their movement is recorded by two cameras. The 2D trajectories of special markers fixed to the hand are extracted from the image sequences and later on their 3D trajectory is reconstructed from individual views. The described method could be useful for an objective description and quantification of certain hand movement disturbances in Parkinson's disease.

Key-Words: - Movement analysis, Parkinson's disease, 3D trajectory reconstruction

1 Introduction

Hand motor function is easily disturbed in neurological disease and this may represent a serious handicap. Lesions in different structures of the central and peripheral nervous systems cause specific disturbances of hand function in the resting position (e.g. resting tremor and dystonia in Parkinson's disease), when movement is initiated (Parkinson's disease), in reaching a target (cerebellar disturbance) etc. [7]. It can be assumed that different lesions would influence also the various phases of a manual transport movement, such as: the forming of the grip, establishing the grip, lifting the object, the transport phases, and placing the object on the target point. A method based on a simple manual transport act could therefore be useful for an objective description and quantification of certain hand movement disturbances.

A manual transport movement is built up by a sequence of isotonic and isometric phases. It consists of reaching for an object (isotonic phase), touching and grasping it (isometric phases) and transporting it to a final goal position (isotonic phases). In the same way release of the grip and return of the hand to its start position can be described. These phases have mostly been studied separately or in short sequences, e.g. reaching only, reaching and grasping [1],[2],[3].

2 Problem Formulation

Many central nervous system disorders are associated with slowness of movement, difficulties in grasping and manipulating things. Changes of movement speed, force development, coordination between grip force and movement forces while grasping an object are measurable variables that can be recorded and quantified to provide an insight in the pathophysiological mechanisms and to document the movement disturbance in an objective way [4],[5],[6]. However, a few objective methods are available in research of human motion. None of them have been accepted in clinical neurology. The aim of this work was to develop a new objective method for quantitative analysis of hand movement and hand movement disturbance in neurological disorder.

3   Problem Solution

For reconstruction of 3D coordinates of moving markers we need at least two views, where the corresponding image points are visible. The reason that at least two views are needed is that one view determines only a line on which the object point must lie, but not the exact position. The second view determines a second line

intersecting the first one in 3D space giving the exact object point position.

Before the camera system can be used to track markers (placed on the patient's hand and to the object), the system first needs to be calibrated. This is done by placing a known calibration frame in front of the cameras (Fig.1) and by running the calibration software on the computer (Fig.2). For our prime experiments we have used Matlab software environment for performing calibration procedure based on direct linear transformation (DLT) [11],[12]. This mathematical model was used in order to calculating intrinsic (focal length, location of the image center, effective pixel size, distortion coefficient of the lens) and extrinsic (rotation matrix, translation vector) camera parameters.

Fig.1 Calibration images of a planar checkerboard from two different views

When the camera system is calibrated the marker recognition algorithm follows. Positions of the markers in the acquired images can be detected manually (off line processing) or by auto-detection algorithms based on the color image segmentation and Hough transformation [9]. The reduced search area for markers detection is implemented. The 3D measuring of moving markers is based on the triangulation algorithm and correspondences between pairs of points (positions of markers) from both of the images purchased by cameras. Given the cameras' internal parameters and relative pose (as result of the calibration) as well as the corresponding image points the 3D position of markers is computed for the sequences of images.
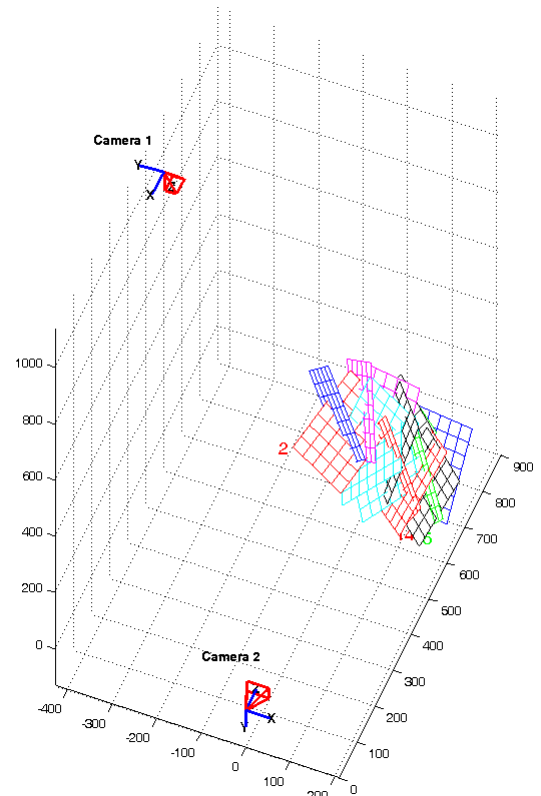

Fig. 2 Calibration is done by placing a known calibration frame in front of the cameras in different positions

3.1 Markers – properties and location

During the motion recording the first marker is attached to the object being moved. The others three markers are attached to the anatomical landmark points on the patient hand. Namely to the head of the second metacarpus (caput metacarpale dig.II), to the lateral and distal side of radius (processus styloideus radii) and to the dorsal side of forearm, approximately 12 cm from the previous marker (Fig.3).
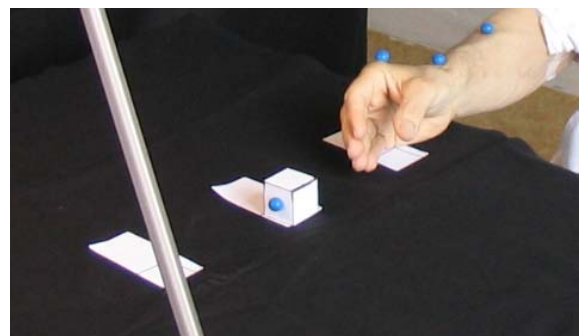

Fig.3 Markers positions. One marker is attached to the object being moved and the others are attached to the patient hand.

There are basically two types of markers, active and passive ones. We have used passive markers due to they are lightweight (no discomfort for the patient) and do not require energy source. The shapes of the markers are spherical so their projection to the image plane has always circular and their position can be determined with high accuracy. In our experiments we have tried out several colors of markers, but finally we have used a blue color, that is also used in professional video applications, as this color does not resemble any of the colors in the human skin.

3.2   Cameras – properties and location

For our experiments we have used two digital video cameras Sony DCR-TRV8E and DCR-TRV210E. The first one was located on the patient's left side recording the hand movement from the side and the second camera was located above the table recording the movement from above (see figures 1., 2. and 4). Both of the cameras are positioned so that all the markers are always seen by them during the measurement. In order to synchronize the video sequences the sync signal was used from an external light emitting diode. Based on this signal the sequences were shifted to the same time base and further processed.

The sampling rate was given by the cameras as 25 frames/s, whereas from the literature is known, that kinetic analysis of human movements can be done with negligible error using this sampling frequency [8].

3.3   3D reconstruction of movement

The 3D location of a set of markers is given by their image projections (2D coordinates of individual markers in image frames) and calibration results (intrinsic and extrinsic parameters). The process of computation is known as stereo triangulation [10],[11]. The results of markers movement are shown in Fig.4 as trajectories on both of the views and Fig.5 illustrates their 3D movement. The derived kinematic quantities are total trajectory, speed of movement, acceleration of movement and change of the angle during the motion.

4   Conclusion

The way, how the brain functions in order to produce motion, cannot be fully understood without objective tools for movement analysis. Objective methods provide a potential for understanding pathophysiology of movement disorders. However, the construction of useful and robust objective tests of motor disability is still in an early phase.

The present paper aimed to describe an objective method for 3D analysis of hand movement. It has a potential to seek underlying pathophysiological mechanisms.
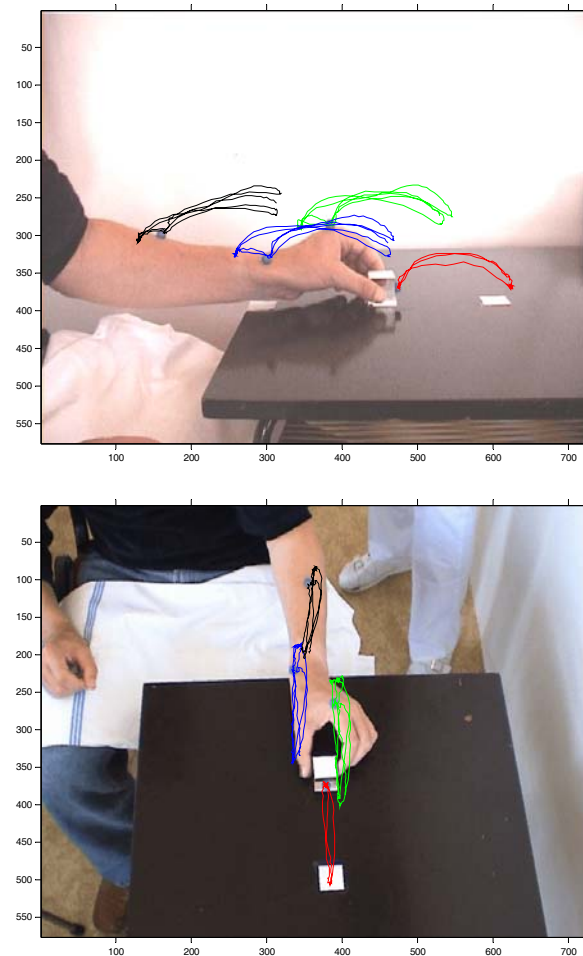

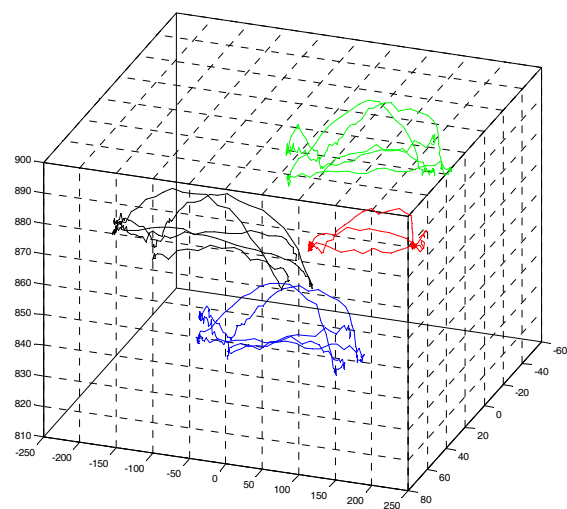*Fig.4 Results of markers detection are illustrated as trajectories on both of the views*

Fig.5 3D reconstruction of the markers trajectories

The method based on manual transport task is presented as a tool to be used in research. To become useful in clinics, further research is needed to ascertain its validity, reliability. The described method cannot replace the existing function tests, however, in combination with them greater precision and objectivity could be gained.

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