Technology in Motion Tremor Dataset: TIM-Tremor

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This dataset was created as part of a larger study on developing patient-friendly techniques for objective quantification of motor (dys)function in patients with neurological disorders. This work was supported by the Netherlands Organisation for Scientific Research (NWO) [Technology in Motion research programme, project 628.004.001]. The funding party played no role in the study design, in the collection, analysis and interpretation of data, or in the decision to submit the dataset or related manuscripts for publication.

1 Patient inclusion and characteristics

Patients were recruited from the outpatient clinic of the Department of Clinical Neurophysiology of the Leiden University Medical Center, Netherlands, between 11 May 2016 and 31 October 2017 (flow chart presented in Figure 1). We included patients aged 18 years or older who (according to their medical records) had an appointment for assessment of tremor in the hand and/or arm. Patients were excluded if they did not have command of the Dutch language or if they were unable to comply with the protocol, i.e. due to insufficient general fitness or cognitive/communicative inability to understand instructions and participate in the measurement. From the 90 consecutive patients who were scheduled for a tremor assessment at the Clinical Neurophysiology outpatient clinic within the inclusion period, 61 patients agreed to participate in our study, of whom 55 were included in the dataset. Informed consent was obtained from all patients according to the Declaration of Helsinki. The ethical committee of the Leiden University Medical Center, Netherlands, approved of the study's protocol before the study was conducted.

2 Measurement instruments and data collection procedure

Data collection occurred in parallel to the standard tremor evaluation at the department of Clinical Neurophysiology (based on electromyography, RGB video and one or two small accelerometers). Except from placing two additional accelerometers on the most affected

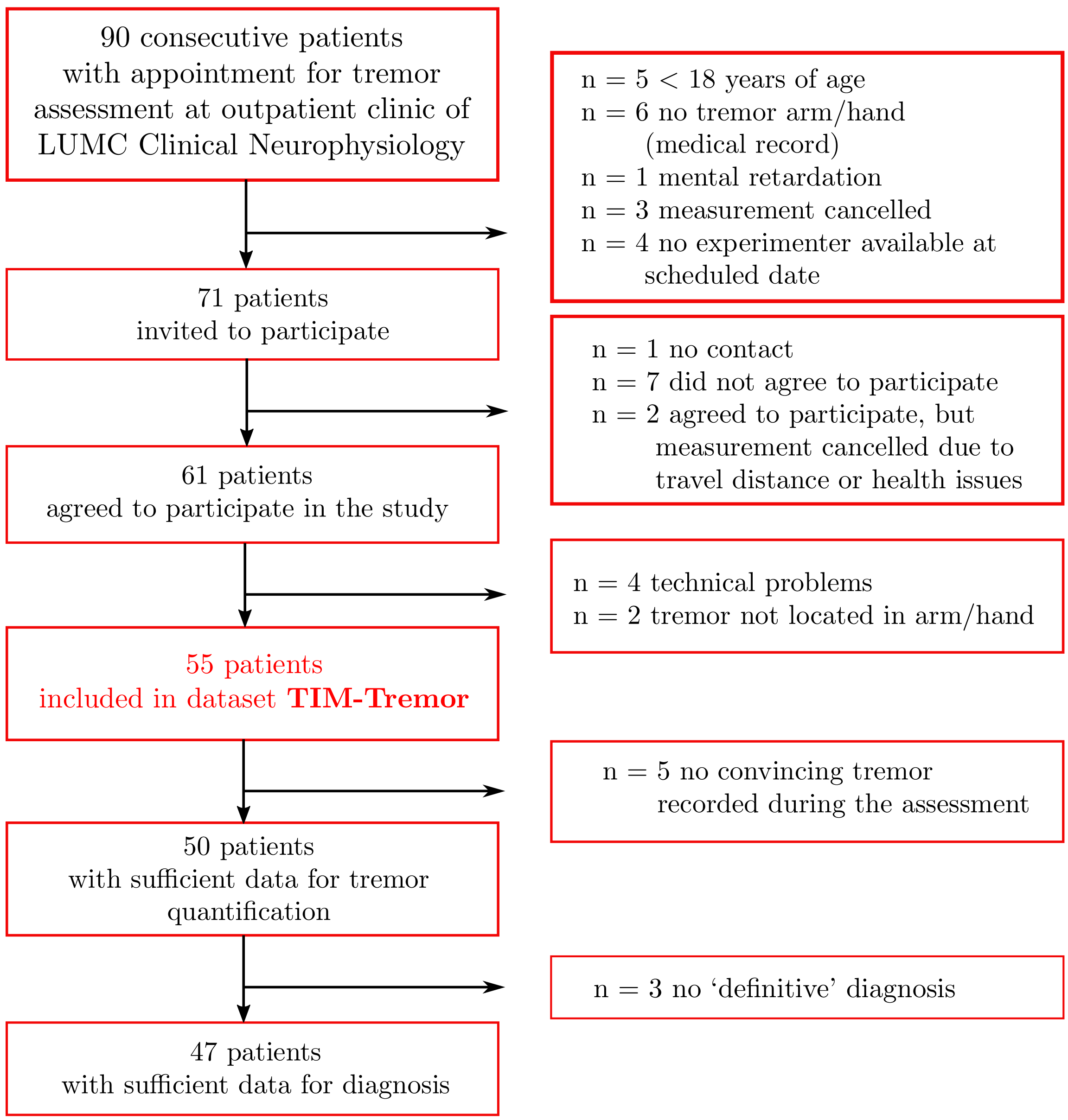


Figure 1: Flowchart of patient inclusion

arm (which served as ground truth in our study, see [**4**]), we did not interfere with the test procedure. Throughout the tests, participants sat in a chair in normal upright position with their feet supported. The tremor evaluation consisted of a set of recordings in variety of poses (e.g. arms outstretched with hand palms facing down) and during various tasks

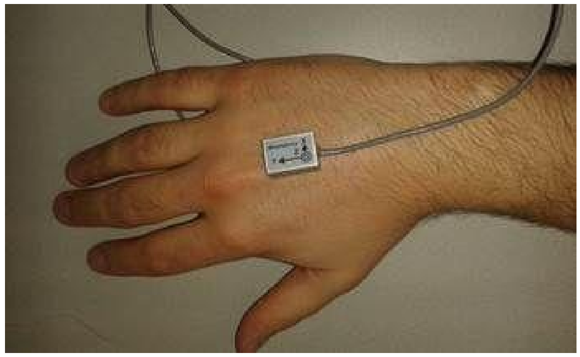


Figure 2: An example of an ACL300 accelerometer sensor used, together with the correct positioning on the hand: z-axis pointing away from the skin surface, while y-axis pointing towards the fingers.

(e.g., during mental distraction).

Tremor severity was evaluated by the experimenter using the Bain and Findley Tremor Clinical Rating Scale [**1**]. The tremor severity of each arm was scored on a scale ranging from 0 to 10 (0: no tremor, 1-3: mild tremor, 4-6: moderate tremor, 7-9: severe tremor, 10: very severe tremor). Diagnostic labels were attributed by the treating neurologist, a specialist in movement disorders, on the basis of available medical information (e.g., history, anamnesis, neurological examination and MRI or DAT scans) in combination with results from the tremor evaluation as provided by the Clinical Neurophysiologist. The following diagnostic labels were used: No convincing tremor, Parkinsonian tremor, Essential tremor, Dystonic tremor, Functional tremor, and Other (please specify).

3 Data description

Microsoft Kinect^{TM} v2 sensor was mounted on a tripod (at a height of circa 1.5 m), placed at a distance of circa 2 m in front of the patient. The Kinect^{TM} v2 sensor consisted of one HD 1920 $\times$ 1080 RGB camera and one time-of-flight device 512 $\times$ 424 16-bit depth images, with a sampling rate of 30 frames per second. A custom-made GUI (MATLAB version R2016a, The Mathworks Inc., Natick MA, USA) was used to control the recordings.

Ground truth data for validation of tremor frequency and amplitude are provided by 2 accelerometers (ACL300, Biometrics Ltd, Newport, UK) taped to the forearm and to back of the most affected hand (at a distance of circa 6 cm proximal and distal to the wrist joint, respectively), with the y-axis pointing towards the fingers and the z-axis pointing away from the skin surface. Accelerometer signals were sampled at 1000 Hz, with a maximum range of values from -4000 to +4000 (corresponding to -10G and +10G, respectively). Figure 2 shows an example of ACL300 accelerometer positioned on the back of the hand.

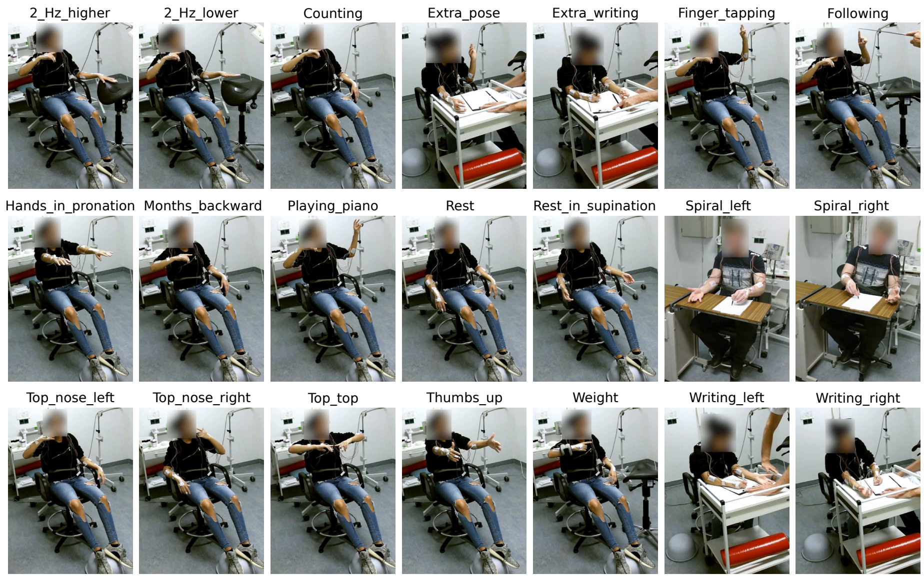
Figure 3: Kinect videos are mirrored. We make a distinction between the *patient's left/right arm* and the *left/right arm in the video*. In this video the two ACL300 accelerometers, highlighted in red, are positioned on the left hand of the patient, but the "accelerometer hand" is annotated as "Right". Therefore, in this video the *patient's arm* is left but the annotated accelerometer *arm in the video* is right. The motivation for this, is that when applying video processing methods, such as the body pose estimation method used in [**4**], the video will be processed as a normal, not mirrored video, where the accelerometer hand will correspond to the right hand, in the video.

3.1 Provided data files

For each patient recording we provide a directory following the naming convention: **T0xx_[Left/Right]**, where **T0xx** denotes a given recording number, and **Left/Right** indicates the mirrored arm on which the accelerometers were positioned. Within each patient directory, a set of subdirectories are found, containing the recordings for the tasks listed in Figure 4.

Note: Kinect records the data mirrored, however, image processing techniques are applied on normal, non-mirrored videos. We, therefore, annotate the accelerometer arm as displayed in the video, rather than as the patient's left/right arm. This distinction is clarified on an example from our dataset, in Figure 3.

We have collected the data in parallel to the standard tremor clinical evaluation. A set of 21 standard tasks are usually performed. These tasks are displayed in in Figure 4.(a)



(a) Recorded tasks.

Task	Description
2_Hz_higher	Tapping in the rhythm of a flashing light, 2 Hz higher than the frequency estimated at rest.
2_Hz_lower	Tapping in the rhythm of a flashing light, 2 Hz lower than the frequency estimated at rest.
Counting	Counting backwards 100-7, with the affected arm outstretched forward.
Extra_pose	Holding a pose proposed by the medical expert to better visualize the tremor.
Extra_writing	Extra writing task with a special pen, or diverging from the standard writing task.
Finger_tapping	Tapping using the index and thumb fingers.
Following	Following a moving pointer, with the index finger of the most affected arm.
Hands_in_pronation	Hands in pronation position.
Months_backward	Naming the months backwards, with the affected arm outstretched forward.
Playing_piano	Moving the thumb across all fingers from the index to the pinky finger, and back.
Rest	Resting the arms on the chair handles.
Rest_in_supination	Resting the arms in supination position, on the chair handles.
Spiral_left	Drawing a spiral with the left hand.
Spiral_right	Drawing a spiral with the right hand.
Top_nose_left	Touching the top of the nose with the left hand.
Top_nose_right	Touching the top of the nose with the right hand.
Top_top	Holding the fingertips in front of each other, with the elbows lifted at 90 degrees angle.
Thumbs_up	Holding the thumbs up with the arms outstretched forward.
Weight	The affected arm outstretched forward, with a weight attached to the wrist.
Writing_left	Writing a given sentence with the left hand.
Writing_right	Writing a given sentence with the right hand.

(b) Explanation.

Figure 4: (a) We record motor-disorder patients in 21 tasks. Each task may elicit a tremor. (b) Short explanation of what each task involves. (Figure taken from [**4**]).

and described in Figure 4.(b). The tasks vary with in the body posture of the patients: e.g. touching the nose, writing, as well as the amount of motion involved: e.g. rest task versus following a pointer. Physical tasks accompanied by a mental task are also recorded such as: *Counting* or *Months_backward*. The changes present in the frequency or the amplitude of the tremor, are important for defining the final diagnostic.

Within each recording directory for every task, we store:

1. The RGB video segment: **kinect.avi** .
   - Sampling rate: 30 frames/second.
   - Size: 1920 px × 1080 px.
2. The corresponding Kinect depth recording, encoded as a grayscale video: **kinect_depth.avi**.
   - Sampling rate: 30 frames/second.
   - Size: 512 px × 424 px.

   (The transformation from the stored depth image values to mm can be performed by applying the scaling: 4000 / 255.)
3. The Kinect depth recording spatially aligned with the RGB video as described in [**2**], also encoded as a grayscale video: **kinect_map.avi**.
   - Sampling rate: 30 frames/second.
   - Size: 1920 px × 1080 px.
4. The corresponding accelerometer recordings obtained from the two sensors (as displayed in Figure 3): **kinect_accelerometer.tsv**
   - Sampling rate: 1000 samples /second.
   - 9-column recording, in "tab-separated" format: (1) sensor-1 x, (2) sensor-1 y, (3) sensor-1 z, (4) ignore, (5) sensor-2 x, (6) sensor-2 y, (7) sensor-2 z, (8) ignore, (9) ignore.

   Columns 4 and 8 of the accelerometer recordings should be ignored, because there was no input on these channels. Column 9 should also be ignored, it contains a digital value that was not used (and therefore not properly set/meaningful).

We provide a labeling file: **TIM-tremor-labeling.csv**, containing for every patient recording the following information, in "comma-separated" format:

1. The arm, as displayed in the video, on which the accelerometers are positioned (see Figure 3).

2. Tremor rating ranging from 0 to 10 of the left arm of the patient (see Figure 3).

3. Tremor rating ranging from 0 to 10 of the right arm of the patient (see Figure 3).

4. Five classes diagnosis: *0 - No convincing tremor, 1 - Parkinsonian tremor, 2 - Essential tremor, 3 - Dystonic tremor, 4 - Functional tremor*, and *5 - Other* (note: multiple labels can be present in one recording).

3.2 Video processing techniques for this data

In [**3**] and [**5**] two motion magnification techniques are proposed which can be readily applied on this data: the method in [**3**] performs motion magnification from RGB video data, while the method in [**5**] performs motion magnification by employing the depth data. Although not thoroughly evaluated over this dataset, the two methods have been successfully applied on this data, in-house.

A novel image processing approach for estimating tremor frequency from RGB video data, comparing an Eulerian phase-based frequency estimation approach with a Lagrangian frequency estimation, is proposed in [**4**]. The work evaluates the accuracy of the tremor frequency estimation on the *TIM-Tremor* dataset. The tremor frequency in [**4**] is numerically assessed against the accelerometer recording positioned on the back of the hand.

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